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LAND FALLOUT STUDIES (U)

SANDIA NATIONAL LABS ALBUQUERQUE NM

DEC 1956

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ITR-1319

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PRELIMINARY REPORT

Operation EDWING

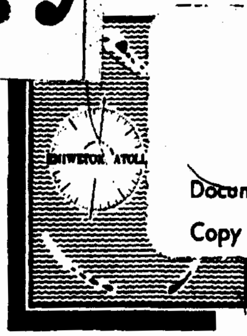
FIC PROVING GROUNDS

1956

LLOUT STUDIES

20

Issuance Date: January 30, 1957



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HEADQUARTERS FIELD COMMAND, ARMED FORCES SPECIAL WEAPONS PROJECT

SANDIA BASE, ALBUQUERQUE, NEW MEXICO

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This is a preliminary report based on all data available at the close of this project's participation in Operation REDWING. The contents of this report are subject to change upon completion of evaluation for the final report. This preliminary report will be superseded by the publication of the final (WT) report. Conclusions and recommendations drawn herein, if any, are therefore tentative. The work is reported at this early time to provide early test results to those concerned with the effects of nuclear weapons and to provide for an interchange of information between projects for the preparation of final reports.

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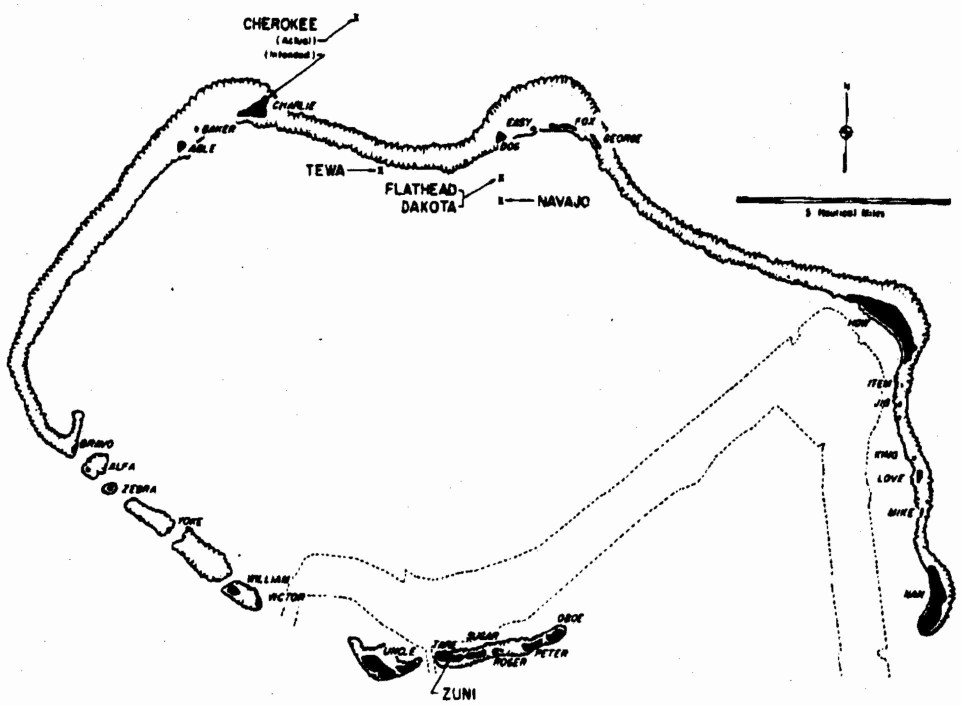
SUMMARY OF SHOT DATA, OPERATION REDWING

Shot Name (Unclassified)	Date (PPG)	Time (Approximate)	Location	Type	E&N Coordinates (Actual Ground Zero)	Geographic ° ' "
Lacrosse	5 May	0629	Eniwetok Yvonne	Surface Land	124515 E 106885 N	11 33 29 162 21 18
Cherokee	21 May	0551	Bikini Off Charlie	Air Drop (4320±150 ft) Over Water	96200 ± 100 E 185100 ± 500 N	11 43 50 165 19 46
Zuni	28 May	0556	Bikini Tare	Surface Land Water	110909 E 100154 N	11 29 48 165 22 09
Yuma	28 May	0756	Eniwetok Sally	200-ft Tower	112155 E 130604 N	11 37 24 162 19 13
Erie	31 May	0615	Eniwetok Yvonne	300-ft Tower	127930 E 102060 N	11 32 41 162 21 52
Seminole	6 June	1255	Eniwetok Irene	Surface Land[a]	75237 E 149897 N	11 40 35 162 13 02
Flathead	12 June	0626	Bikini Off Dog	Barge Water	115768 E 164094 N	11 40 22 165 23 13
Blackfoot	12 June	0626	Eniwetok Yvonne	200-ft Tower	126080 E 104435 N	11 33 04 162 21 33
Kickapoo	14 June	1126	Eniwetok Sally	300-ft Tower	114018 E 132295 N	11 37 41 162 19 32
Osage	16 June	1314	Eniwetok Yvonne	Air Drop (680±35 ft) Over Land	126647 ± 50 E 102851 ± 50 N	11 32 48 162 21 39
Inca	22 June	0956	Eniwetok Pearl	200-ft Tower	105300 E 133540 N	11 37 53 162 18 04
Dakota	26 June	0606	Bikini Off Dog	Barge Water	116767 E 164097 N	11 40 22 165 23 13
Mohawk	3 July	0606	Eniwetok Ruby	300-ft Tower	109737 E 132165 N	11 37 39 162 18 49
Apache	9 July	0606	Eniwetok Flora	Barge Water	69227 E 148063 N	11 40 17 162 12 01
Navajo	11 July	0556	Bikini Off Dog	Barge Water	116816 E 160604 N	11 39 48 165 23 14
Tewa	21 July	0546	Bikini Charlie-Dog Reef	Barge Water	99776 E 164476 N	11 40 26 165 20 22
Huron	22 July	0616	Eniwetok Flora	Barge Water	70015 E 148304 N	11 40 19 162 12 09

[a] See ITR-1344 for further details.



Airukiiji	Oboe	Bokoaetokutoku	Alfa	Eniirikku	Uncle	Rochikarai	Love
Airukirare	Peter	Bokobyaadaa	Able	Eninman	Tare	Romurikku	Fox
Aomoen	George	Bokonejien	Baker	Enyu	Nan	Rukoji	Victor
Arriikan	Yoke	Bokonfuaaku	Item	Ionchebi	Mike	Uorikku	Easy
Bigiren	Roger	Bokororyuru	Bravo	Namu	Charley	Yomyaran	Jig
Bikini	How	Chieerete	William	Ourukaen	Zebra	Yurochi	Dog
		Eniairo	King	Reere	Sugar		

Bikini Atoll. Locations of test detonations during Operation REDWING are indicated by large lettering and arrows. Native island names with corresponding military identifiers are given in the tabulation.

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ABSTRACT

Project 2.65 studied the fallout resulting from three land-surface shots, two water-surface shots, and one air burst to: (1) obtain fallout samples and perform radiophysical and radiochemical measurements on the samples; (2) prepare dose-rate contours in the immediate area of the atoll from information gathered by this project, other projects, and Rad-Safe; and (3) evaluate the role of base surge in the transport of radioactive material.

Time incremental and gross fallout samples were collected on islands of Bikini Atoll, on a barge in Bikini Lagoon, and on three ships in the downwind fallout area following Cherokee, an air burst; Zuni and Tewa, land-surface shots; and Navajo and Flathead, water-surface shots. Gross fallout samples were collected on islands of Eniwetok Atoll following Lacrosse, a land-surface shot.

Contamination levels existing at specific points on the islands were measured following Shots Lacrosse, Zuni, Flathead, Mohawk, Navajo, and Tewa by the lowering of a probe from a helicopter to a distance of 3 feet from the ground surface.

Base-surge detectors, consisting basically of a photovoltaic cell upon which a light beam was focused, were installed at a few close-in stations for Zuni, Flathead, Navajo and Tewa.

No fallout over the atoll was observed following the Cherokee air drop. All fallout collectors were monitored, as was a dirt sample from the intended ground zero, but no activity was detected.

Preliminary analysis of the fallout samples from the other events provided information on the gamma dose rate decay; the beta decay rate; the weight, activity, radiochemical composition, time of arrival, rate, and duration of fallout; and on the nature of individual fallout particles. There was good agreement between early field and laboratory dose rate decay slopes. The decay exponent for Lacrosse was about -1.35; for all other events, the decay exponent fluctuated around -1.0.

The fallout resulting from the water-surface shots differed in nature from that of the land-surface shots. In the case of Flathead, most of the activity was associated with a slurry, or mud, which contained $CaCO_3$ particles, Fe_2O_3 particles, and NaCl crystals. In the case of Navajo, most of the activity was associated with liquid fallout and with a slurry of NaCl crystals. The Lacrosse and Zuni fallout, on the other hand, consisted chiefly of particles derived from coral. In the samples examined for Lacrosse and Zuni, a large majority of the particles making up the fallout were radioactive throughout their volume.

The capture-to-fission ratios varied with type of fallout and distance from ground zero. Furthermore, the cloud samples from Zuni and

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Lacrosse had lower ratios than the solid fallout. The activity per unit weight of fallout resulting from land-surface bursts was higher at distant stations than at relatively close-in stations.

(b) (3)

An aerial survey instrument provided a practical means of determining precise contamination levels at surface locations in a high-radiation field. The maximum radiation intensities measured on the ground near the Lacrosse and Mohawk craters were higher than those reported after any previous nuclear detonation. Consistent H+1 hour dose rates from 10,000 to 13,000 r/hr were obtained in the neighborhood of the Mohawk crater.

No results are available at this time on the evaluation of the role of base surge in the transport of radioactive material.

FOREWORD

This report presents the results of one of the 48 projects participating in the Military Effects Program of Operation REDWING, which included 17 test detonations.

For readers interested in other pertinent test information, reference is made to ITR-1344, Summary Report of the Commander, Task Unit 3. This summary report includes the following information of general interest: (1) an overall description of each detonation, including yield, height of burst, ground zero location, time of detonation, and ambient atmospheric conditions at detonation; (2) a discussion of all project results; (3) a summary of each project, including objectives and results; and (4) a complete listing of all reports covering the Military Effects Program.

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TABLES

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CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

The work performed during Operation REDWING by Project 2.65 was a logical extension of fallout studies conducted during previous nuclear tests. The project was responsible for land fallout studies, one phase of an extensive program on fallout. The studies should help to increase the knowledge of weapon effects and provide measurements of value in the construction and evaluation of fallout-prediction models.

The objectives of Project 2.65 were to: (1) obtain fallout samples on land and perform radiophysical and radiochemical measurements on the samples; (2) prepare dose-rate contours in the immediate area of the atoll from information gathered by this project, other projects, and Rad-Safe; and (3) evaluate the role of the base surge in the transport of radioactive material.

1.2 MILITARY SIGNIFICANCE

When a nuclear explosion occurs on or near the surface of land or water, radioactive debris is later deposited over the surface as fallout. This contamination constitutes a radiation hazard which must be considered in both offensive and defensive planning. Many offensive and defensive procedures pertinent to the use of nuclear weapons depend upon accurate definition of the extent and location of the radioactive area. Some of the present work was designed to determine the residual-radiation patterns resulting in the immediate area of the atoll so that, in combination with other projects, complete residual-radiation patterns could be developed.

It is also important to be able to predict the fallout, including dose-rate contours, time of arrival, rate of arrival, duration, and rate of decay. For this purpose several agencies have proposed prediction models (Reference 1). In order to evaluate these models, the effects listed above must be documented during tests of nuclear devices. The various fallout-prediction models are based on different assumptions regarding the nature of the bomb cloud. These assumptions are necessitated by the lack of basic input data; e.g., particle-size distribution, distribution of activity with particle size, and spatial distribution in the cloud. Some of these data can be measured directly on fallout samples, but others must be derived from fallout measurements in conjunction with

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Operation CROSSROADS (Reference 3). Since it was an unexpected occurrence, little in the way of base-surge data was obtained, and conflicting conclusions were drawn concerning the role of the base surge in carrying activity. Documentation of the base surge was first carried out systematically during the JANGLE underground shot, but only a limited amount of information was obtained. Basic physical effects data were obtained, but the question of base-surge activity was not resolved. An analysis of the time of arrival of activity, radiochemical data, photography, and all other available information from the underground shot during TEAPOT indicated that the base surge was the primary carrier of activity in the upwind and crosswind directions (Reference 4). It is unknown whether the high-yield surface detonations of Operations IVY and CASTLE produced a base surge. Attempts to sample base surge during Operation CASTLE were thwarted by the destruction of the raft measuring stations by heavy seas.

The ideas on particle formation developed from the results of Operation CASTLE, in conjunction with the accepted model of base surge formation, indicated that a radioactive base surge would be deficient in gaseous precursor nuclides, such as Sr^{89} and Ba^{140}. (Sr^{89} and Ba^{140} have 2.6 m Kr^{89} and 16 s Xe^{140} parents respectively.) Because of the chemical inertness of these gases, they cannot become appreciably associated with particles until some decay has taken place. Hence, material which leaves the cloud very early should be deficient in these nuclides (Reference 16). The TEAPOT results appear to confirm this theory, but the unusual nature of the test makes it inadvisable to extrapolate the results to detonations at a lesser scaled depth.

<u>1.3.4 Salted Weapons.</u> Proposals have been made recently to salt thermonuclear weapons by incorporating into them elements whose neutron-capture products would control the radiological hazard of fallout (Reference 17). Small amounts of several candidate elements were placed in the Navajo device during REDWING in order to evaluate the feasibility of salting. Some of these elements were incidentally included in the Zuni device, but in less favorable locations. Radiochemical analyses for the reaction products were necessary for the estimation of the efficiency of the process.

An intermittent fallout collector, a gross fallout collector, and a Project 2.2 dose-rate recorder were placed on the Project 2.63 instrument platforms located on the landing ship, LST-611, and the converted Liberty ships, YAG-39 and YAG-40.

Instrumentation of Eniwetok Atoll for Lacrosse was limited to Sites Leroy, Wilma, Yvonne, and Mack (Table 2.5 and Figure 2.2). Each of these stations included a gross fallout collector and a Signal Corps film packet. Since participation during Mohawk was limited to aerial survey, no stations were instrumented for the shot.

2.2 FIELD OPERATIONS

2.2.1 Installation of Equipment. Installation of equipment at the station locations was begun approximately 30 days before the ready date for the first event. Each station was located in a cleared area on the

TABLE 2.2 INSTRUMENTATION OF PROJECT 2.65 STATIONS FOR NAVAJO

Site	Intermittent Fallout Collectors (IFC)	Gross Fallout Collectors (GFC)	Base Surge Detectors (BSD)	Tape Fallout Monitors (TFM)
Charlie	5	3	0	1
Fox	1	0	1	0
George	2	1	1	1
How	5	1	0	1
Love	1	1	0	0
Nan	2	0	0	0
Oboe	2	1	0	0
Uncle	2	1	0	0
William	2	1	0	0
Yoke	2	1	0	1
Bravo	1	1	0	0
Able	1	1	0	0
YFNB-29	1	1	0	0
YAG-39	1	1	0	0
YAG-40	1	1	0	0
LST-611	1	1	0	0

part of the island site where water-wave inundation was least likely to occur, i.e., on the highest part of the island and on the side farthest from the nearest ground zero.

The arrangement of the instruments at a typical land station is shown in Figure 2.3. The intermittent fallout collectors were placed within concrete support foundations so designed that the collecting trays were approximately 2 feet 8 inches above the surrounding ground level. Where more than one collector was placed at a station, they were 10 feet apart, center to center.

Each gross fallout collector was mounted on a concrete base adjacent to the intermittent fallout collector and was bolted to one end of the foundation for the intermittent fallout collector. The opening of each collector was approximately 4 feet above ground level.

Each tape fallout monitor was bolted to the top of the foundation used for the intermittent fallout collector so that the collection surface was about 4 feet above ground level.

The base surge indicators were located in the same cleared areas, approximately 10 feet away from the other instruments.

Installation of equipment on the YFNB-29 barge is shown in Figure 2.4.

2.2.2 Aerial Survey. Aerial survey points on the islands of each atoll were located prior to the first event through the use of aerial photographs, maps, and visual reconnaissance. These points were selected on the basis of the availability of cleared areas and the proximity of these areas to the center of the island.

The aerial survey instrument described in Appendix A was calibrated before each shot on the Project 2.1 calibration range at Site Elmer. The instrument was then shipped to Bikini for installation in the survey helicopter. At the completion of the survey for each shot, the instrument was returned to Elmer, and the calibration procedure was repeated in order to make certain that no change had occurred during shipment and use in the field.

TABLE 2.3 INSTRUMENTATION OF PROJECT 2.65 STATIONS FOR TEWA

Site	Intermittent Fallout Collectors (IFC)	Gross Fallout Collectors (GFC)	Base Surge Detector (BSD)	Tape Fallout Monitors (TFM)
Charlie	2	0	0	0
Fox	0	0	1	0
George	3	3	0	0
How	5	1	0	1
Love	1	1	0	0
Nan	2	0	0	0
Uncle	2	1	0	0
William	2	1	0	0
Bravo	1	1	0	0
Able	1	1	0	0
YFNB-29	1	1	0	0
YAG-39	1	1	0	0
YAG-40	1	1	0	0
LST-611	1	1	0	0

After each shot, the survey mission began as soon as clearance was granted by Commander, Task Group 7.1. In most cases, this was at about H+7 hours. For the Bikini events, the survey began on Site Nan and proceeded around the atoll in a counterclockwise direction, ending at Oboe. For Shots Lacrosse and Mohawk, at Eniwetok Atoll, the survey mission began on Site Elmer and proceeded around the atoll until the southern chain of islands was reached. These missions were repeated on D+1 and D+2 days for each shot.

The probe was lowered through the side door of the H-19 helicopter as it hovered at an altitude of about 600 feet above a check point on the ground. When the tripod support touched the ground, the probe was at a point 3 feet above the surface, and a reading was taken. The operator then reeled in a portion of the cable, and the helicopter moved to the next check point, where the procedure was repeated. Figure 2.5 shows the probe and tripod support being lowered from a survey helicopter.

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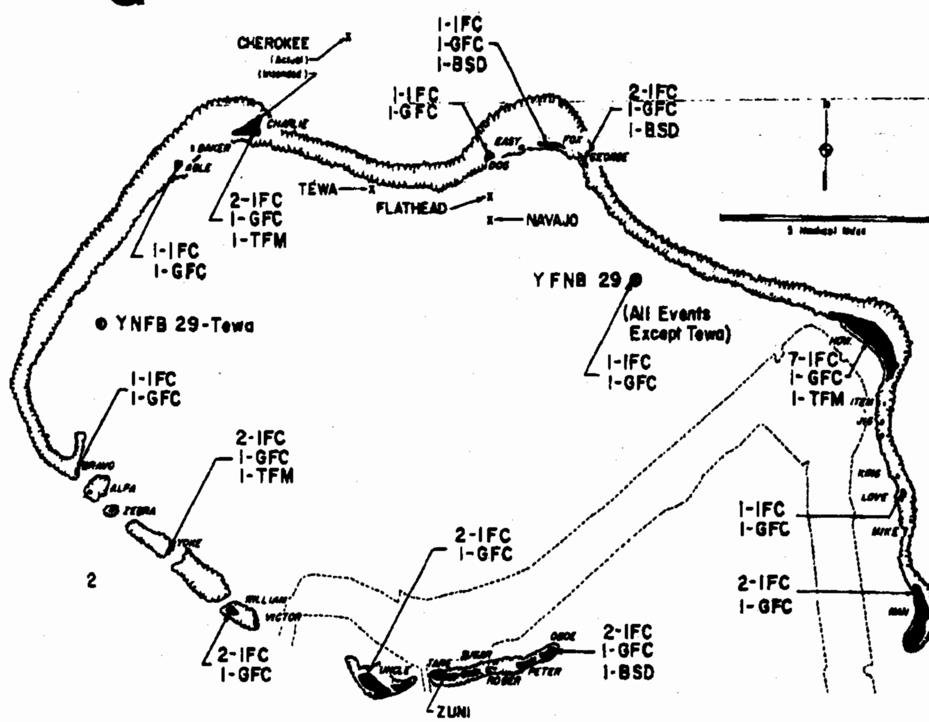

Figure 2.1 Basic station layout for Bikini Atoll.

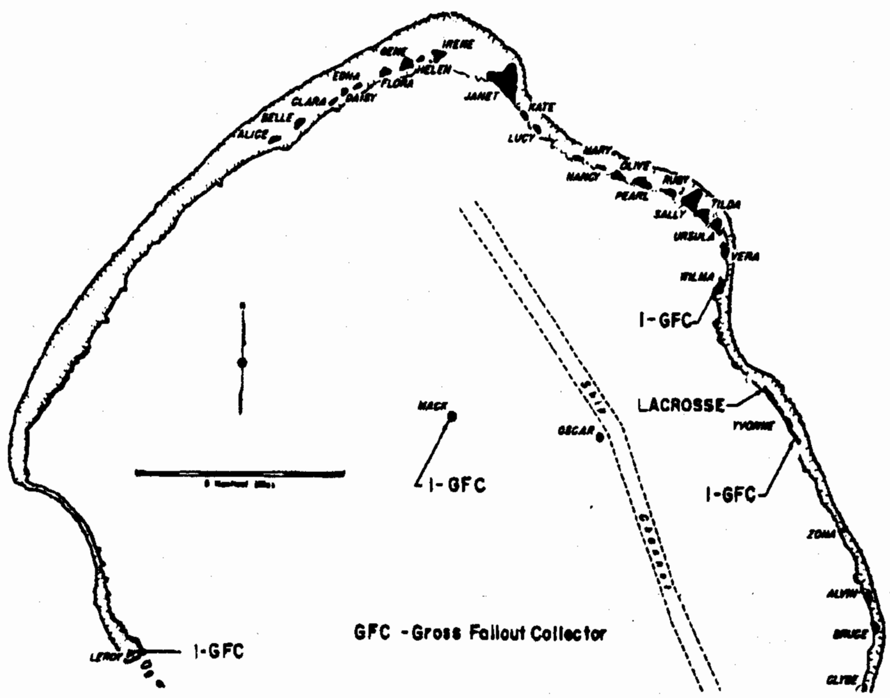

Figure 2.2 Project 2.65 stations for Lacrosse.

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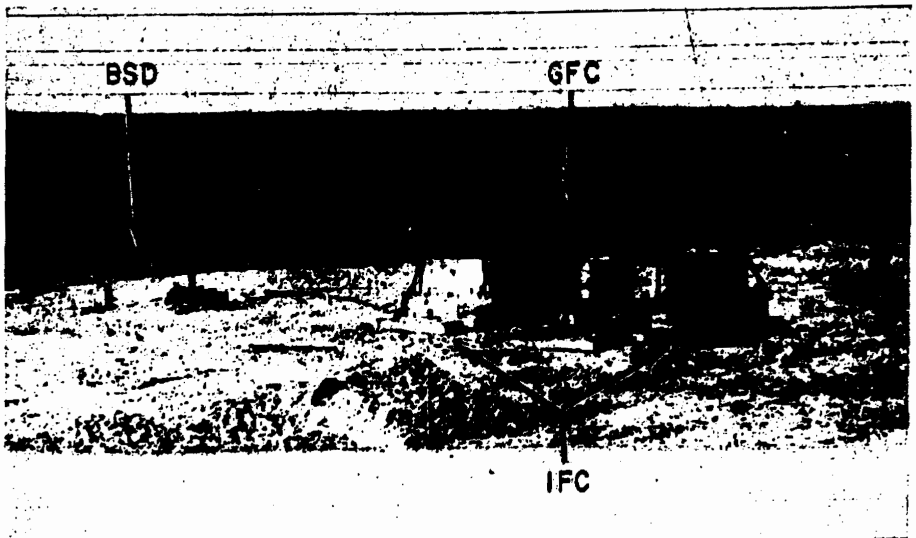

Figure 2.3 Project 2.65 station showing two intermittent fallout collectors (IFC), one gross fallout collector (GFC), and one base-surge detector (BSD).

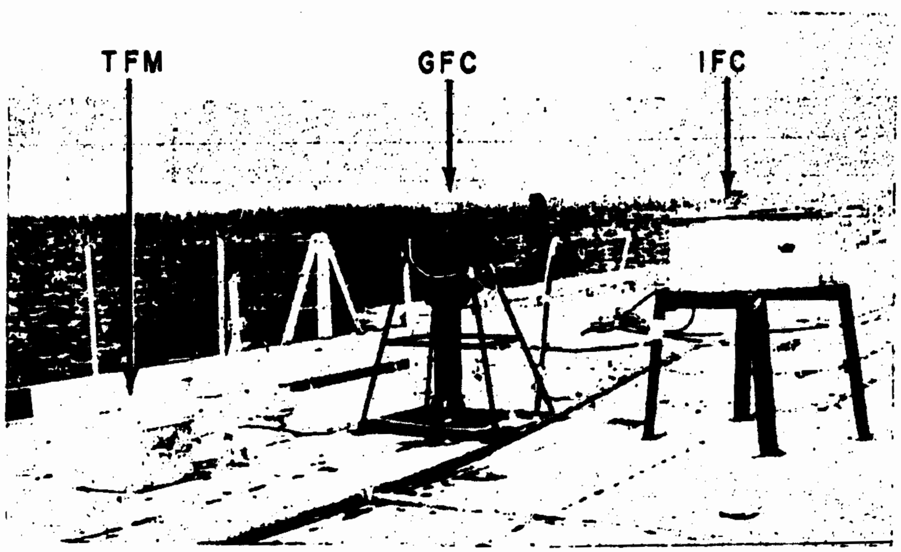

Figure 2.4 Project 2.65 station on YFNB-29, showing tape fallout monitor (TFM), gross fallout collector (GFC), and intermittent fallout collector (IFC).

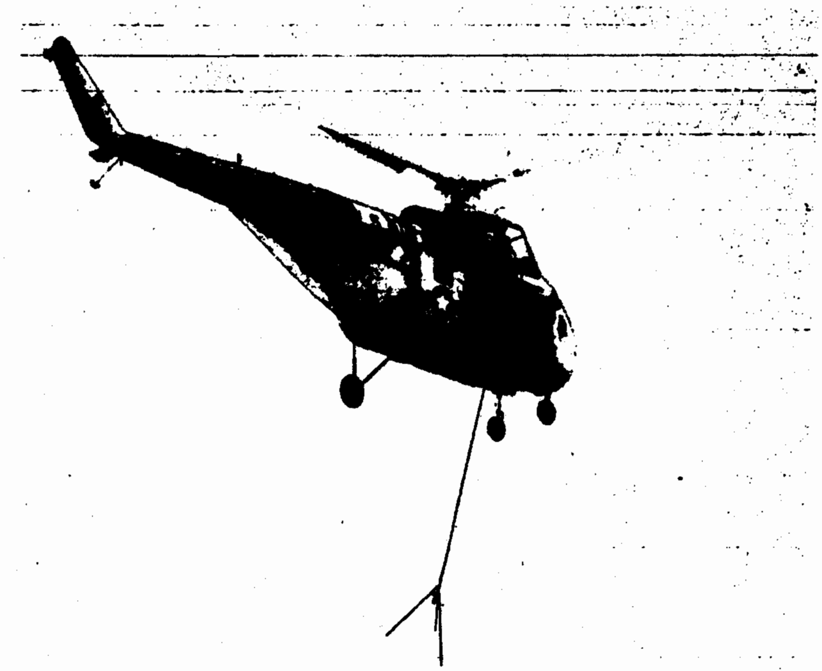

Figure 2.5 Probe and tripod being lowered from H-19 helicopter.

Conversion factors for changing dose-rate readings for various altitudes above ground to the equivalent reading at the 3-foot level were obtained by taking gamma dose-rate readings at various altitudes above Site Charlie. These readings were obtained by raising the probe to successively higher levels as the helicopter hovered at its initial altitude. Conversion factors as obtained were not directly used for the present analysis, which uses the readings taken at 3 feet. These data, combined with other factors which take into account the geometry of the activity will eventually provide a basis for correlation between readings taken at an altitude above the ground and those taken at 3 feet.

For Shots Lacrosse, Mohawk, and Zuni, readings were taken as close to the crater as was consistent with safety to personnel in the helicopter.

2.2.3 Recovery of Samples. Two gross fallout samples were recovered by helicopter on D-day for each Bikini shot. These samples were obtained as early as possible, so that early decay measurements could be started. The remaining samples from the gross fallout collectors, the intermittent fallout collectors, and the tape monitors on the island stations were recovered on D+1 day after each event. Samples from the LST and the two YAG's were recovered as soon as they returned to the Bikini or Eniwetok Lagoon.

For the Bikini events, the island samples were brought to Site Nan, where they were prepared for shipment to Eniwetok. All samples arrived at the field laboratory on Site Elmer (of Eniwetok Atoll) by D+2.

For Shot Lacrosse, all samples were available for analysis on D+1 day.

2.3 ANALYTICAL PROCEDURES

2.3.1 Aerial Survey. The raw aerial survey data were corrected by means of the instrument calibration curves which were obtained prior to each shot. Details of the calibration procedure, along with a typical calibration curve, are given in Appendix A. Field gamma decay curves were taken then drawn for several of the islands included in the survey by use of the values obtained between D-day and D+2 days. The decay exponent for each set of readings was then obtained, and the average value was used for correction of the measured dose-rate readings to the equivalent H+1 hour values.

Conversion factors for changing dose-rate readings for various altitudes above ground to the equivalent reading at the 3-foot level were obtained by the plotting of the ratio of ground reading to altitude reading against probe height above ground.

2.3.2 Weight and Activity of Fallout. The intermittent fallout samples which were dry were carefully brushed from each tray into the attached bottle, and the total weight of the sample was determined by standard balance techniques. A portion of each sample to be used for activity analysis was then placed in a previously weighed, stainless-steel cup and the weight determined. The amount of the sample taken was kept between 5 and 10 mg, in order to minimize self-absorption in the sample. The sample was then counted in precision beta-counting equipment. The counting equipment and procedures and the corrections necessary for determining activity in disintegrations per minute are described in Appendix B.

Intermittent-fallout samples which contained both liquid and solid were filtered using the Fisher filtrator and Whatman No. 42 filter paper. The filter paper was ashed, and the weight of the residue was determined. Portions were then taken for activity analysis as described above. The total volume of the filtrate was obtained and aliquots of from 1 to 1,000 lambda* (depending on the specific activity) were pipetted into stainless-steel counting cups. These cups were dried under infrared lamps and counted in the usual manner.

Samples from the gross-fallout collectors were first weighed and an aliquot taken for beta activity per unit weight. These samples were treated in the same manner as the IFC samples described above. Weight and activity per unit area of sampling surface were then plotted as a function of particle size.

The portion of several gross-fallout-collector samples remaining after aliquots were taken for beta activity per unit weight, beta decay, and gamma-dose-rate decay were size-separated with U. S. standard sieves. The sieving separated the particles into the following size ranges: 0 to 44 μ, 44 to 74 μ, 74 to 105 μ, 105 to 149μ, 149 to 210μ, 210 to 420μ, 420 to 840μ, and greater than 840μ. All size ranges were weighed, and an aliquot of each was placed in a stainless-steel counting cup and weighed again. From these weights and the activity of the aliquots, activity versus particle size for the fallout samples was obtained.

*1 lambda = 10^{-6} liters.

TABLE 2.4 DISTANCES IN FEET AND AZIMUTHS OF PROJECT 2.65 STATIONS FROM GROUND ZERO FOR BIKINI SHOTS

Station	Zuni	Flathead	Navajo	Tewa
Able	78,340 330°	46,120 275°	46,400 278°	29,090 276°
Charlie	78,080 338°	36,780 287°	37,790 289°	20,420 299°
Dog	69,920 5°	5,640 2°	8,050 1°	—
Fox	72,720 13°	11,960 54°	13,470 46°	—
George	71,800 17°	15,070 71°	15,970 63°	31,690 84°
How	77,210 52°	56,670 107°	56,000 104°	72,240 105°
Love	72,240 70°	73,020 124°	71,160 125°	88,020 118°
Nan	68,770 86°	86,150 134°	84,490 135°	99,360 128°
Oboe	16,310 78°	62,150 172°	58,680 172°	—
Uncle	10,500 259°	68,010 194°	65,690 195°	64,530 179°
William	35,000 285°	78,100 213°	75,320 214°	59,400 199°
Yoke	43,100 293°	66,630 224°	64,200 225°	56,240 210°
Bravo	59,800 298°	67,960 238°	68,770 239°	56,820 227°
YFNB-29	55,300 32°	28,440 124°	28,440 120°	41,400 235°
YAG-39	480,480 350°	153,120 8°	105,600 351°	121,440 335°
YAG-40	279,840 2°	311,520 22°	174,240 339°	211,200 307°
LST-611	—	158,400 318°	232,320 265°	290,400 322°

TABLE 2.5 PROJECT 2.65 STATIONS FOR LACROSSE

Island	Coordinates (Holmes and Narver)		Distance From Ground Zero	No. of Gross Fallout Collectors	No. of Film Packets
	N	E	ft		
Wilma	110,920	110,800	14,000	1	1
Yvonne	100,010	120,910	8,000	1	1
Leroy	70,170	30,240	97,500	1	1
Mack	100,370	80,640	37,500	1	1
Gene	148,820	71,180	69,000	0	0

2.3.3 Particle-Size Measurements. Portions of all size-graded samples were placed on NTB stripping film mounted on plastic rings for radioautography. A mixture of xylene and silicone was added to hold the sample in place, and the sample was exposed for 24 hours. All NTB film was processed at the test site and returned to the Army Chemical Center for analysis. Particle-size distributions and the ratio of active to inactive particles in each size range will be determined.

2.3.4 Decay Measurements. Measurements of beta decay were taken for all intermittent-fallout collector intervals which contained samples counting 1,000 counts per minute or more at initial counting.

Aliquots from gross-fallout collectors were used for beta decay measurements, as well as for gamma decay measurements.

The sample to be measured was transferred to a stainless-steel counting cup for beta-decay measurements and to a glass planchet for gamma dosage decay measurements. It was then immobilized with a small amount of silicone resin diluted with toluene in order to facilitate counting and handling procedures.

The counting technique for beta decay measurements is described in Appendix B. The counting for gamma dosage decay measurements was done using a Jordan AGB-10-SR survey meter with the sample placed in a fixed geometry 1 inch away from the meter surface. The AGB-10-SR survey meter is the same as the AGB-10K-SR meter, described in Appendix A, except that the upper range limit is 10 r/hr.

Decay measurements were begun at H+24 hours or less and continued at the test site for a period ranging from 100 to 1,000 hours. The samples were then returned to the Army Chemical Center, where the analysis was continued. For the first 100 hours, the samples were counted once every 24 hours. At later times they were counted every other day.

Curves of field gamma-dose-rate decay were plotted from aerial and ground survey data taken at the same locations on successive days from H+8 hours to H+50 hours.

2.3.5 Time of Arrival, Rate, and Duration of Fallout. The time of fallout arrival at each station was determined from the analysis of the samples collected by the intermittent fallout collector and from the tape monitor data.

Samples from the intermittent fallout collectors were prepared and counted with precision beta counting equipment, as described previously in Section 2.3.2.

Counting was begun at about H+50 hours, and all activities were corrected back to this standard time. The decay exponent used for this purpose was derived from the early beta decay curves obtained from these samples. Counts per minute were converted to disintegrations per minute, as described in Appendix B.

The total activity per sampling interval was then plotted as a function of time. From these graphs, the time of arrival, the time for the maximum rate of fallout, and the time at which significant fallout ends were determined.

Additional time of arrival data were determined from the tape fallout monitor. Relative activities were determined by monitoring the individual sections of the tape with a Beckman MX-5 G-M survey meter.

CHAPTER 3

RESULTS AND OBSERVATIONS

Useful data were obtained by this project following each of the shots in which participation was planned except for Shot Cherokee. The yields and locations of these shots are tabulated in Table 3.1.

No fallout was observed over the Bikini Atoll following the Cherokee air drop. All fallout collectors were monitored, nevertheless, and an earth sample was scooped from the area of the intended ground zero. This

TABLE 3.1 EVENTS IN WHICH PROJECT 2.65 PARTICIPATED

Shot	Atoll	Type of Shot	General Location	Preliminary Yield
Lacrosse	Eniwetok	Land Surface	Yvonne	(b) (3)
Cherokee	Bikini	Air Drop	NE of Charlie	
Zuni	Bikini	Land Surface	Tare	
Flathead	Bikini	Barge	Lagoon Off George	
Mohawk	Eniwetok	300-ft Tower	Ruby	
Navajo	Bikini	Barge	Lagoon Off Dog	
Tewa	Bikini	Land Surface	Over reef between Charlie and Dog	

sample, as well as those from the collectors, showed no activity resulting from the event. Since the actual ground zero was over water and not upwind from the atoll, no data were obtained relative to the presence of contamination following a megaton-range air burst.

Dose-rate contours within the area of the atolls have not yet been constructed by this project for any of the events listed in Table 3.1. For Shot Lacrosse no data were collected for the water area of the lagoon. For the Bikini events, dose-rate data were obtained for the water area within the lagoon by Projects 2.62 and 2.63. It is anticipated that these data will have been reduced to the equivalent infinite plane land-surface readings in time for inclusion in the final report of Project 2.65.

The field equipment used by this project operated satisfactorily in most cases. In those instances where intermittent and gross fallout collectors failed to function, the difficulty was usually due to failure of the blue boxes to trigger the circuits involved. Despite these failures, more than 75 percent of the collectors operated satisfactorily for Shots Lacrosse, Zuni, Flathead, Navajo, and Tewa.

Operational difficulties were experienced with the base surge detectors, due to the effect of the shock wave in some cases and to the fact that the H-1 minute signal was not received at the station in one instance. In another case, the station was not instrumented, because of the predicted height of the water wave.

After two of the events, useful samples were obtained from sources other than the fallout collectors. After Shot Lacrosse, ground scoop samples were obtained from Sites Wilma and Gene, and another was retrieved from a depression in the canvas top of an abandoned truck at Gene. After Shot Zuni, a large sample was scooped from the forward deck house of the YAG-40 following the ship's return to Bikini Lagoon on D+2 day.

No useful samples were obtained at the distant fallout station at Rongerik Atoll. The station there was not activated for any shot except Zuni. After the Zuni event, the inside liner of the total fallout collector was returned to Site Elmer and surveyed for beta plus gamma activity with an MX-5 survey meter. An insignificant amount of activity was noticed. Brushing the liner yielded no useful solid fallout sample. Post-shot examination of available records revealed that there was, in fact, no significant fallout at Rongerik.

3.1 DECAY MEASUREMENTS

3.1.1 Gamma-Dose-Rate Decay. Early field gamma dose rate decay curves resulting from aerial survey data are shown in Figures 3.1 to 3.5. These curves, based upon the measurements made on D-day, D+1, and D+2, reflect the field decay rate for the period from H+8 hours to H+50 hours. A straight line was fitted to the three points by inspection, and the slope of the line was determined by measurement from the graph. No field decay curves were obtained for Navajo, because of the effect of the heavy rains which occurred on D+1 day.

Laboratory gamma dose rate decay measurements obtained from selected gross fallout collector samples for each shot are shown in Figures 3.6 to 3.10. The time interval covered was from approximately 20 hours to several hundred hours.

In general, all gamma dose rate decays for Shot Lacrosse were similar to that shown in Figure 3.6 for the solid sample obtained from the gross fallout collector on Site Wilma. The liquid sample from this same collector exhibited a markedly different decay, as shown in Figure 3.7. This difference cannot be explained at this time.

All Shot Zuni samples exhibited similar decay curves between H+40 and H+600 hours. A representative gamma decay curve from Zuni gross fallout is shown in Figure 3.8.

A gamma dose rate decay curve from Shot Flathead is shown in Figure 3.9 and one from Shot Navajo in Figure 3.10. Some samples show deviations from these decay curves. Later analysis of all decay data will provide information which may make possible the construction of a composite decay curve for each shot. Consequently, no curves have been drawn through the data points presented in the figures. In addition, due to the preliminary nature of the data, the counting errors have not been evaluated.

The decay slope determined from these graphs of gamma dose rate decay for Shots Lacrosse, Zuni, Flathead, and Navajo are listed in Table 3.2.

The slopes listed for the Zuni and Navajo curves are based upon the straight line passing through the first three points which cover the period from H+20 to H+50 hours. This time period was used in the table in order that the laboratory and field measurements would cover the same period.

3.1.2 Beta Decay. Beta decay data were obtained from gross fallout collector samples and from all intermittent fallout collector samples having sufficiently high activities. Representative decay curves for each shot are shown in Figures 3.11 to 3.16. Curves for both liquid and solid

TABLE 3.2 EARLY GAMMA-DOSE-RATE DECAY SLOPES

	Lacrosse	Zuni	Flathead	Mohawk	Navajo	Tewa
Field Gamma Decay Slope (H+8 to H+50 hours)	-1.36	-0.92	-1.0	-1.1	—[b]	-1.08
Laboratory Gamma Decay Slope (H+20 to H+50 hours)	-1.33	-0.90	-1.2	—[a]	-1.02	—[c]

[a]Samples not collected for this shot

[b]Heavy rains prevented evaluation of field decay slope.

[c]High background at Site Elmer prevented determination.

fallout samples are included for Shots Lacrosse and Zuni. In each case, appreciable differences are observed in the shape of the curves for the two types of samples. The decay curve for Flathead, shown in Figure 3.15, is representative of those liquid and solid samples which had relatively high activity at the time of initial counting.

3.2 AERIAL SURVEY DATA

All survey data were corrected through the use of the instrument calibration curves obtained immediately prior to each event. The calibration procedure and a typical calibration curve are included in Appendix A.

3.2.1 Shot Lacrosse. The aerial survey readings obtained on Sites Zona through Daisy are shown in Table 3.3. The H+1 hour dose rates were determined by using a decay exponent of -1.36 as obtained from the field gamma decay curves of Figure 3.1. These H+1 hour values are shown on a map of the atoll (Figure 3.22).

Aerial survey readings were not obtained on Site Alice, and the value shown was calculated from Rad-Safe ground readings.

All survey readings taken over the reef near the crater were obtained during low tide. The reef had been washed over by at least two high tides between shot time and time of the survey. The calculated H+1 hour dose rates for Site Yvonne and the adjacent reef are shown in Figure 3.18. The one abnormally high reading near the edge of the crater lip was obtained on D+1 day. No other comparable dose rate levels were observed during the survey. The crater was partially filled with water at all times, and no readings were attempted over the crater or lip.

3.2.2 Shot Zuni. Aerial survey readings obtained on islands of Bikini Atoll after this shot are shown in Table 3.4. The H+1 hour dose rates were determined by using a decay exponent of -0.92, obtained from

[redacted] [redacted]

TABLE 3.4 CORRECTED AERIAL SURVEY READINGS, ZUNI
(field gamma decay exponent: -0.92)

Site	Survey Point	Time After Shot	Corrected Reading	H+1 hr Dose Rate	Average H+1 Hr Dose Rate
		hr	mr/hr	r/hr	r/hr
Love	1	8.1	130	0.89	1.2
		32.75	50	1.2	
		56.0	40	1.6	
Nan (South)	1	8.2	700	4.9	5.7
		33.0	290	7.2	
		56.1	120	4.9	
Nan (Center)	2	8.25	1,400	9.8	11
		33.0	470	11.7	
		56.1	280	11.4	
George	1	8.4	12,000	85	91
		33.2	3,700	93	
		56.3	2,300	94	
Fox	1	8.5	13,000	72	93
		33.3	4,300	108	
		56.3	2,400	98	
Dog	1	8.5	13,000	72	89
		33.3	4,000	101	
		56.3	2,300	94	
Charlie (Center)	1	33.4	4,000	101	96
		56.4	2,200	90	
Charlie (Northeast)	2	8.75	11,000	81	86
		33.5	3,700	94	
		56.5	2,000	82	
Able	1	8.9	12,000	90	82
		33.5	3,100	78	
		56.6	1,900	78	
Bravo	1	9.1	3,100	24	22
		33.7	820	21	
		56.8	530	22	
Zebra	1	9.2	2,700	21	21
		33.8	870	22	
		56.8	500	21	
William	1	33.9	1,600	41	40
		56.9	920	38	
Uncle (West end)	1	34.0	980	25	26
		57.0	620	26	
Oboe	1	34.1	1,500	39	38
		57.1	870	36	

3.2.4 Shot Mohawk. The aerial survey covered the portion of Eniwetok Atoll which was contaminated to a significant extent by this event. This included the sites between Janet and Sally. The largest number of readings was taken on the close-in sites, Pearl, Ruby, and Sally. Since Pearl and Sally were the sites of previous detonations, varying contamination levels existed on portions of these islands prior to Mohawk. Therefore, the H+1 hour dose rates due to Mohawk were not calculated in these instances. For Sites Olive through Janet, the actual readings were corrected by subtraction of the small dose rates existing prior to the shot. The preshot readings on the south end of Pearl and the north end of Sally were negligible when compared to the post-Mohawk readings.

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[redacted]

TABLE 3.6 CORRECTED AERIAL SURVEY READINGS, MOHAWK
(field gamma decay exponent: -1.10)

Site	Survey Point	Time After Shot	Corrected Reading	H+1 hr Dose Rate	Average H+1 hr Dose Rate
		hr	mr/hr	r/hr	r/hr
Janet	1	9.43	985	11.6	
		31.5	285	13.4	12.0
		55.6	135	11.1	
Kate	1	9.48	985	11.7	
		31.6	275	13.0	11.9
		55.7	135	11.1	
Lucy	1	9.53	935	11.1	
		31.6	335	15.0	12.7
		55.7	145	12.0	
Mary	1	9.58	135	1.80	
		9.88	125	1.74	
		31.7	45	2.02	1.70
		55.8	15	1.25	
Olive (North)	1	9.92	35	0.42	
		9.63	35	0.42	
		31.7	15	0.67	0.50
		55.8	5	0.41	
Olive (South)	1	9.95	110	1.38	
		31.8	50	2.24	2.71
		55.9	55	4.50	
Pearl (North)	1	9.97	1,700	a	a
		31.8	2,700	a	a
		55.9	3,000	a	a
Pearl (Center)	1	9.97	1,200	a	a
		31.8	600	a	a
		56.0	150	a	a
Pearl (South)	1	10.0	50,000	627	
		10.0	48,000	603	
		31.8	22,000	990	755
		56.0	9,500	798	
Sally (Center)	1				
		32.4	4,300	b	b
		56.4	3,500		
Sally (North)	1	9.33	41,000	478	
		32.4	12,000	550	473
		56.4	4,600	391	
Ruby	1	31.8	34,000	1,560	
	2	31.9	50,000	2,250	
	3	32.2	180,000	8,290	
	4	31.9	200,000	8,990	
	5	32.2	250,000	11,500	
	6	32.3	230,000	10,600	
	7	32.3	215,000	9,900	
	8	32.3	84,000	3,870	
	9	32.3	285,000	13,100	
	10	32.4	285,000	13,200	
	11	56.1	78,000	6,550	
	12	56.1	110,000	9,230	
	13	56.1	105,000	8,810	
	14	56.2	130,000	10,900	
	15	56.2	100,000	8,400	
	16	56.3	150,000	12,600	
	17	56.3	130,000	10,900	

[a] These readings were not extrapolated to H+1 hr due to uncertainty of residual contamination from Shot Inca.
[b] These readings were not extrapolated to H+1 hr due to uncertainty of residual contamination from Shots Nickapoo and Yuma.

[redacted]

[redacted]

TABLE 3.7 CORRECTED AERIAL SURVEY READINGS, NAVAJO
(laboratory gamma decay exponent: -1.02)

Site	Day	Time After Shot	Corrected Reading	H+1 hr Dose Rate
		hr	mr/hr	r/hr
How	N	6.97	110	0.8
	N+1	34.6	10	
George	N	7.12	4,500	33.6
	N+1	34.7	170	
Fox	N	7.17	6,000	45.0
	N+1	34.8	520	
Dog	N	7.32	8,000	61.6
	N+1	34.8	125	
Charlie	N	7.43	6,000	46.9
	N+1	34.9	130	
Able	N	7.53	6,200	49.1
	N+1	35.0	280	
Bravo	N	7.72	230	1.9
	N+1	35.2	52	

TABLE 3.8 CORRECTED AERIAL SURVEY READINGS, TEWA
(field gamma decay component: -1.08)

Site	Day	Time After Shot	Corrected Reading	H+1 hr Dose Rate	Average H+1 Reading
		hr	mr/hr	r/hr	r/hr
Uncle	T	8.98	4,000	43	
	T+1	32.5	1,000	43	42
	T+2	57.1	500	39	
William	T	9.17	19,000	210	
	T+1	32.4	6,500	280	230
	T+2	57.0	2,500	195	
Zebra	T	9.28	38,000	420	
	T+1	32.3	9,200	395	425
	T+2	56.8	5,900	465	
Bravo	T	9.33	19,000	210	
	T+1	32.3	9,200	395	320
	T+2	56.8	4,600	360	
Able	T+1	32.1	37,000	1,570	1,455
	T+2	56.6	17,000	1,335	
Charlie	T+1	32.0	37,000	1,570	1,485
	T+2	56.5	18,000	1,400	
Dog	T+1	31.9	16,000	670	630
	T+2	56.4	7,500	585	
Easy	T+1	31.8	15,000	630	580
	T+2	56.3	6,800	530	
Fox	T+1	31.8	13,000	545	470
	T+2	56.1	5,000	390	
George	T+1	31.7	7,400	310	325
	T+2	56.1	4,300	335	

[redacted]

may exist in regard to actual quantities of activity collected. Cumulative activity as a function of time after shot for the Charlie station is shown in Figure 3.34. The reason for the branch between the curves for the two collectors is not understood.

The fallout arrival data for Sites Oboe, William, Yoke, and Charlie are summarized in Table 3.9. The times of arrival and maximum rates were read directly from the graphs of the 5-minute-interval collector data for William, Yoke, and Charlie. The time of cessation was read from the graphs of the 30-minute-interval collector data for these stations.

Similar data were not available for Sites Dog, Fox, and George, because the collectors at these stations did not operate. The data obtained from the instruments at the station on How, where the fallout

TABLE 3.9 TIME, RATE, AND DURATION OF FALLOUT FOR SHOT ZUNI

Site	Distance From Ground Zero	Azimuth From Ground Zero	Time of Arrival	Time to Maximum Rate of Fallout	Time of Cessation
	ft	deg	min	min	hr
Oboe	16,310	80	16-17	19-20	
William	35,000	286	15-20	25-30	2-2.5
Yoke	43,000	293	30-35	35-40	1-1.5
Charlie	78,000	336	40-45	85-90	3-3.5

activity was relatively low, showed little correlation from one collector to another.

3.4.2 Shot Flathead. Twenty five of the 33 intermittent fallout collectors used for this event operated successfully. Significant levels of fallout were observed only on Sites Able through George. At all stations on these islands, fallout was collected during the first 30 minutes after shot. A more precise determination of time of arrival cannot be made, since quantitative agreement was not obtained between instruments using different sampling intervals at the same locations. In general, the overall level of activity of the samples collected in the intermittent fallout collector for Flathead was lower by two orders of magnitude than the level of similar samples collected after Zuni. This was true in spite of the fact that the levels of contamination produced on the islands in question were of the same order for the two events. A discussion of the reasons for this apparent anomaly is included in Section 4.5.

Data resulting from 30-minute-interval collectors on Charlie and George are shown in Figures 3.35 and 3.36. These data indicate that the maximum rate of collection of fallout occurred between $1\frac{1}{2}$ and 2 hours after shot.

The survey readings obtained from the record of the tape fallout monitor on George are plotted in Figure 3.37. The record indicates that the fallout stopped at H+10 hours and started again at approximately H+$15\frac{1}{2}$ and continued until H+18 hours. The value plotted for the first 56 minutes was obtained by summing the values obtained from the 2-minute-interval samples collected during this period. Small amounts of activity were recorded for each of these early intervals.

[redacted]

per unit weight was not calculated.

In order to obtain an estimate of the total activity collected, the surface of the cone was monitored before and after removal of the solid adhering to the walls. The sintered stainless-steel filter was washed with a solution containing versene and hydrochloric acid. The fraction of the total activity remaining in the collector and on the filter was then estimated. After the application of the necessary corrections, the total activity collected was determined by adding together the activity in the solid, that found in the filter, and the activity of the original sample. The sample activities listed in Table 3.10 resulted from these estimates.

Weight and activity measurements resulting from Shot Tewa will appear in the final report.

Weight and activity distribution as a function of particle-size range is shown graphically for one Lacrosse sample and four Zuni samples

TABLE 3.12 ACTIVITY PER UNIT AREA OF COLLECTION SURFACE FOR OFC AND IFC FLATHEAD SAMPLES

Site	Sample Type	Sample Activity at H+50 hr	Sampling Area	Activity Per Unit Area at H+50 hr
		10^9 dis/min	ft^2	10^9 dis/min/ft^2
Able	OFC mud	124.0	2.73	45.4
	OFC loose particles	0.17	2.73	0.06
	OFC total sample	124.17	2.73	45.5
Fox	OFC mud	136.0	2.73	49.8
	OFC loose particles	1.12	2.73	0.41
	OFC total sample	137.12	2.73	50.2
Charlie	IFC loose particles	0.0586	0.125	0.47
	IFC total sample	a	a	a
George	IFC loose particles	0.0514	0.125	0.41
	IFC total sample	a	a	a

[a] See text.

in Figures 3.46 to 3.50. The Lacrosse sample was obtained from the top of a truck canvas, while the Zuni samples were obtained from gross fallout collectors.

3.6 EXAMINATION OF INDIVIDUAL PARTICLES

3.6.1 Shot Lacrosse. The studies were all made on the sample obtained from the canvas top of a truck cab on Site Gene. Figure 3.51 is a photomicrograph of a portion of the 210-to-420-micron size range. Five general types of particles were found: (1) opaque coral; (2) translucent coral; (3) black, sintered particles; (4) transparent crystalline particles; and (5) spherical black particles.

The first two types generally characterize particles of natural coral. Most of the coral particles in the fallout had yellow and black spots on their surfaces. The black, sintered particles were ferromagnetic and gave a positive test for iron with potassium ferrocyanide and potassium thiocyanate. The source of the iron may have been the unusually large amount of pipe extending from and around ground zero. In many cases the interior of these particles was coral. All spherical black particles (Type 5) were black throughout. The transparent crystals gave a positive

[redacted]

The YAG-40 deck sample was heavily agglomerated in the particle size region above 210 microns. These agglomerates were resistant to mechanical pressure, but the application of water rapidly broke them down into particles of 50 microns or less. The resulting solution gave a strong test for chloride ion.

Particles of Types 1 and 2 appeared to be homogeneous mixtures of $CaCO_3$ and CaO or $Ca(OH)_2$. They were generally free of the yellow and brown spots observed after Shot Lacrosse. Type 1 particles gave a positive test for chloride ion.

The spheres appeared to be CaO or $Ca(OH)_2$, with a surface coating of $CaCO_3$. After the samples had been stored for several weeks, spheres could no longer be found. The spheres that had been sectioned swelled and erupted out of the plastic mounts after several weeks, in some cases cracking the plastic. In this form they were a loose mass of tiny crystals.

TABLE 3.15 FREQUENCIES OF PARTICLE TYPES IN ZUNI FALLOUT

Sample Location and Size Range	Particle Type	Frequency of Type	Frequency of Hot Particles	Frequency of Volume Activity Among Hot Particles	Frequencies of Surface Activity Among Hot Particles	Number of Particles Counted
μ		pct	pct	pct	pct	
Yoke 149 to 210	Opaque	46	38	100	0	226
	Translucent	53	42	100	0	
	Spherical	1	100	100	0	
Yoke 210 to 420	Opaque	60	56	94	6	460
	Translucent	39	50	100	0	
	Spherical	1	100	100	0	
Yoke 420 to 840	Opaque	63	58	14	86	345
	Translucent	27	65	55	45	
	Spherical	10	90	85	15	
Bravo 149 to 210	Opaque	53	95	95	5	565
	Translucent	45	60	100	0	
	Spherical	2	100	100	0	
Bravo 210 to 420	Opaque	63	73	87	13	1199
	Translucent	31	37	97	3	
	Spherical	6	100	98	2	
Bravo 420 to 840	Opaque	77	88	2	98	606
	Translucent	17	34	80	20	
	Spherical	6	95	100	0	
Charlie 149 to 210	Opaque	75	82	100	0	375
	Translucent	24	37	100	0	
	Spherical	1	100	100	0	
Charlie 210 to 420	Opaque	58	73	72	28	155
	Translucent	37	81	98	2	
	Spherical	5	100	85	15	
Charlie 420 to 840	Opaque	85	83	13	87	136
	Translucent	12	55	100	0	
	Spherical	3	100	100	0	
YAG-40 149 to 210	Opaque	46	100	100	0	612
	Translucent	36	100	100	0	
	Spherical	18	100	100	0	
YAG-40 210 to 420	Opaque	63	100	100	0	327
	Translucent	28	100	100	0	
	Spherical	9	100	100	0	

[redacted]

[redacted]

TABLE 3.16 FRACTIONATION IN LACROSSE FALLOUT

Sample	Particle Size
	μ
Wilma Ground	0- 44
	44- 74
	74-105
	105-149
	149-210
	210-420
Gene Ground	0- 5
	5- 14
	10- 22
	16- 32
	26- 40
	40- 50
	44- 74
	74-105
	105-149
	149-210
	210-420
Gene Canvas	0- 44
	44- 74
	74-105
	105-149
	149-210
	210-420
	420-840
	Total Solid
LASL Cloud Sample	

(b) (3)

[a]This error term is a measure of the internal consistency of the analysis procedure as related to four aliquots.

TABLE 3.17 ACTIVITY CONCENTRATIONS IN LACROSSE FALLOUT

Sample	Particle Size
	μ
Gene Canvas	0- 44
	44- 74
	74-105
	105-149
	149-210
	210-420
	420-840
	Total Solid

[redacted]

A few metallic-looking flakes, which gave a strong test for iron, were observed.

It should be noted that the YAG-40 deck sample was exposed to a large volume of rain before and after cessation of fallout and, presumably, to significant salt spray.

The bulk density of the sample of fallout from the Bravo collector was 2.17 g/cm^3.

3.6.3 Shot Flathead. Three types of fallout were found: (1) brown mud; (2) discrete, solid particles; and (3) liquid. The brown mud accounted for more than 99 percent of the total activity in the Able and Fox gross fallout collectors. Very little liquid was collected. The pattern of the mud on the walls of the collectors has been described in Section 3.5. The mud consisted of fine coral particles, sodium chloride, and a large quantity of Fe_2O_3, suspended in water droplets about 1 or 2 mm in diameter. This material was hard to remove after it had dried on the walls of the collectors. Laboratory equipment used in handling this material was also difficult to decontaminate, and recovery personnel had extreme difficulty decontaminating their hands and shoes.

The discrete, solid particles exhibited a wide variety of types, but $CaCO_3$ predominated. As was pointed out above, these particles did not contribute significantly to the activity.

3.6.4 Shot Navajo. Particles from the Charlie gross fallout collector were examined under the microscope. At least 80 or 90 percent of them were fine crystals of NaCl which were hygroscopic and tended to agglomerate. Most of the remaining particles were $CaCO_3$. There were some small pieces of shiny metal, probably aluminum scraped from the collector during removal of the sample. No iron was detected. Since NaCl was predominant, further study of the particles was not considered worthwhile.

3.7 RADIOCHEMISTRY

3.7.1 Shot Lacrosse. Only the Wilma total fallout collector was within the fallout area, and it collected only a small sample. However, a sample (designated "Wilma ground") was scooped from the ground at this location at approximately H+10 hours. Late on D+1 four samples were obtained from Gene. These consisted of three samples from the ground, which were combined and designated "Gene ground," and a sample from the canvas top of a truck cab (designated "Gene canvas").

(b) (3)

(b) (3)

The present values are estimated to be accurate within 25 percent.

3.7.3 Shot Flathead. Radiochemical results from this shot are given in Tables 3.20 and 3.21.

(b) (3)

The analyses reported show excellent agreement between the Fox and Able mud.

3.8 BASE-SURGE RESULTS

Base-surge detectors were installed at one or more stations for Shots Zuni, Flathead, Navajo, and Tewa. During Shot Zuni, the station on Oboe failed to receive the H-1 minute signal, and the operation of the stations on Fox and George for Shot Navajo was interrupted by water waves. The only complete record obtained was from the instrument on Fox at a distance of 11,960 feet from the Flathead ground zero. The record did not show any indication of the presence of base surge at this station.

(b) (3)

TABLE 3.20 RELATIVE FRACTIONATION OF NUCLIDES IN FLATHEAD FALLOUT

Sample
Charlie IFC
hr
0 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 4
4 - 6
6 - 7.5
7.5 - 9
9 - 10.5
Weighted Average
Fox IFC
min
0 - 1
1 - 2
3 - 5
5 - 7
7 - 9
9 - 14
14 - 17
17 - 19
20 - 21
Weighted Average
Fox OFC Mud
Able OFC Mud
Fox OFC Particles
George OFC Liquid

(b) (3)

(b) (3)

TABLE 3.21 CONTRIBUTIONS OF NUCLIDES TO FLATHEAD GROSS ACTIVITY

Sample
Charlie IFC
hr
0 - 1
1 - 1.5
1.5 - 2
2 - 2.5
2.5 - 4
4 - 6
6 - 7.5
7.5 - 9
9 - 10.5
Weighted Average
Fox IFC
min
0 - 1
1 - 2
3 - 5
5 - 7
7 - 9
9 - 14
14 - 17
17 - 19
20 - 21
Weighted Average
Fox OFC Mud
Able OFC Mud
Fox OFC Particles

(b) (3)

[redacted]

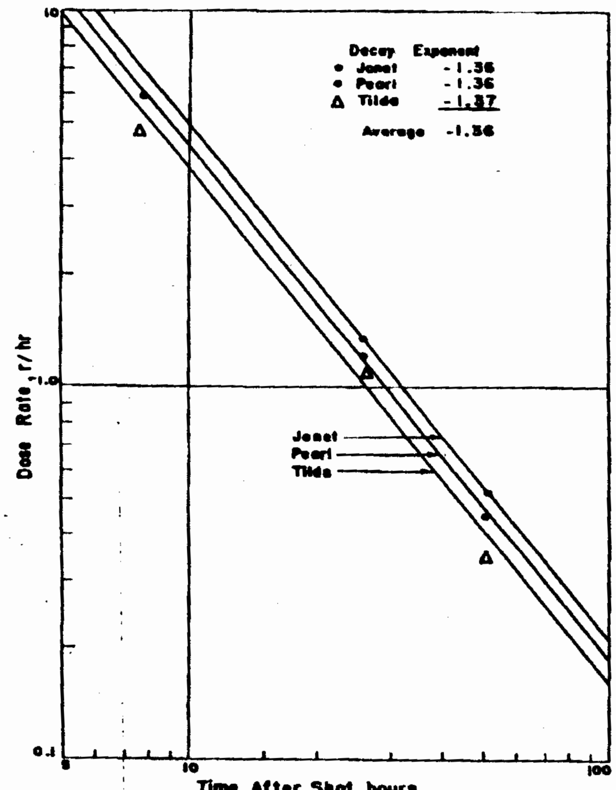

Figure 3.1 Field gamma-decay curve from Lacrosse aerial survey.

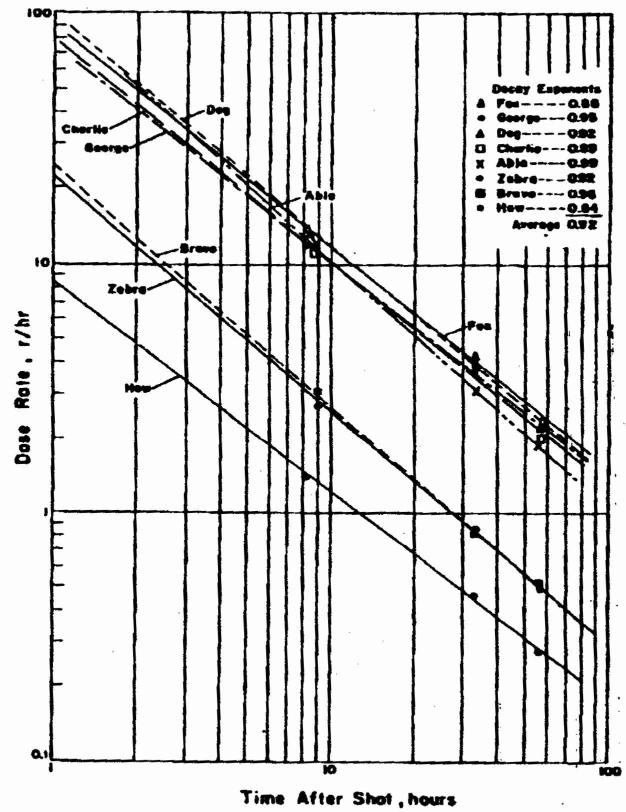

Figure 3.2 Field gamma-decay curve from Zuni aerial survey.

[redacted]

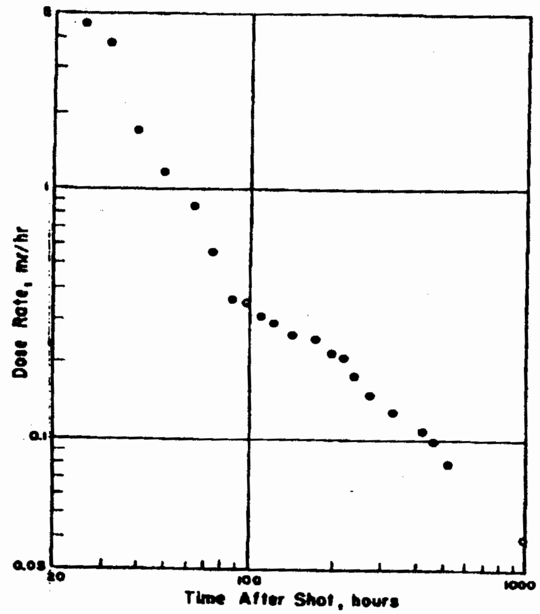

Figure 3.7 Laboratory gamma-dose-rate-decay curve of a liquid sample from Shot Lacrosse.

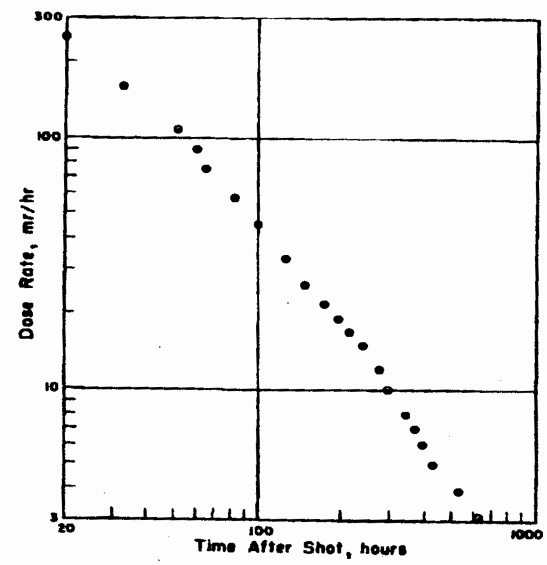

Figure 3.8 Laboratory gamma-dose-rate-decay curve of a sample from Shot Zuni.

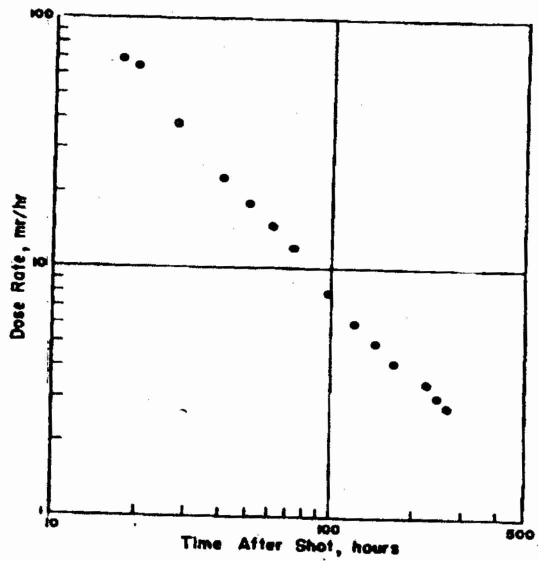

Figure 3.9 Laboratory gamma dose-rate-decay curve of a sample from Shot Flathead.

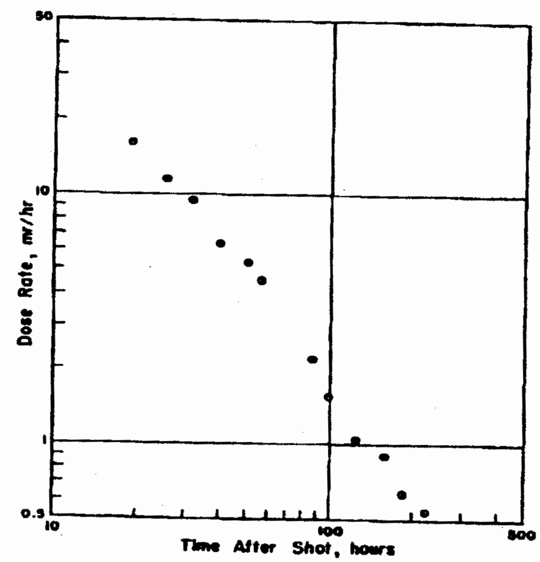

Figure 3.10 Laboratory gamma dose-rate-decay curve of a sample from Shot Navajo.

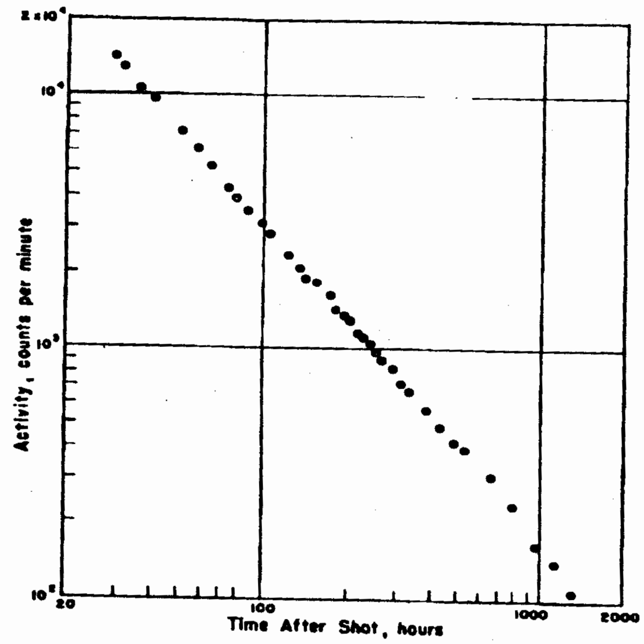

Figure 3.11 Laboratory beta decay curve of a solid sample from Shot Lacrosse.

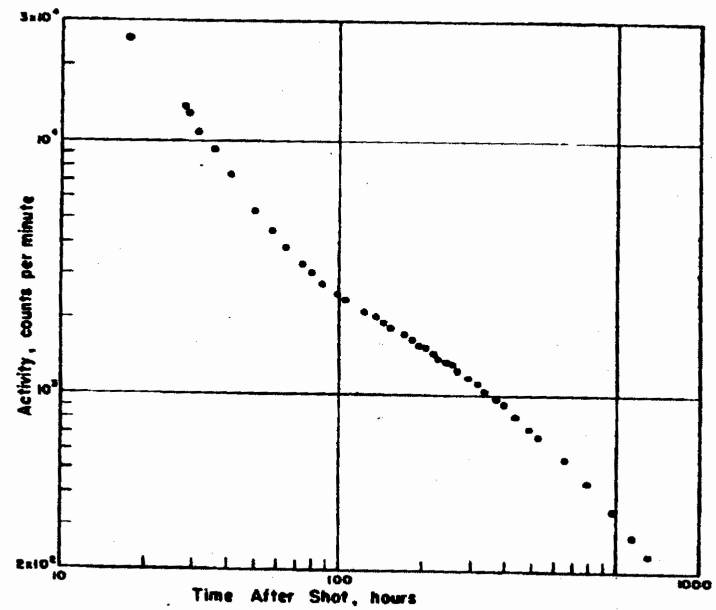

Figure 3.12 Laboratory beta decay curve of a liquid sample from Shot Lacrosse.

[redacted]

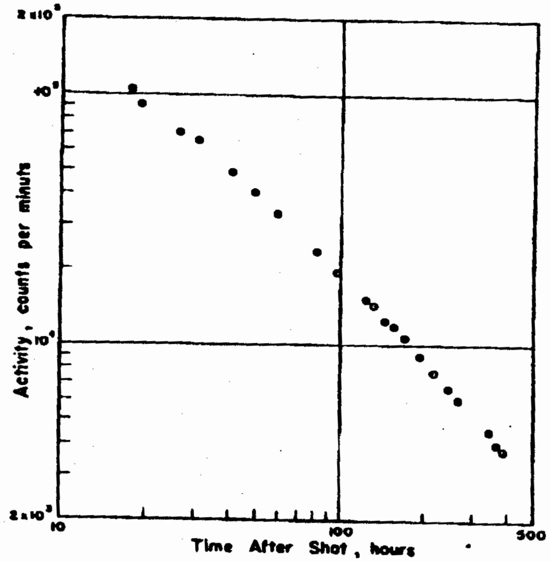

Figure 3.15 Laboratory beta decay curve of a liquid-and-solid (mud) sample from Shot Flathead.

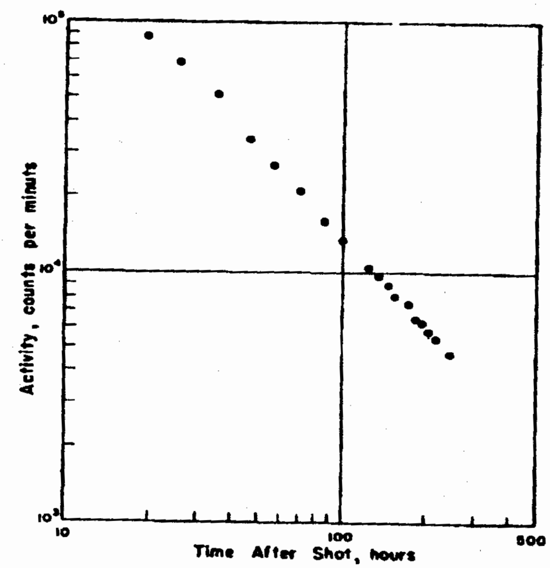

Figure 3.16 Laboratory beta decay curve of a solid sample from Shot Navajo.

[redacted]

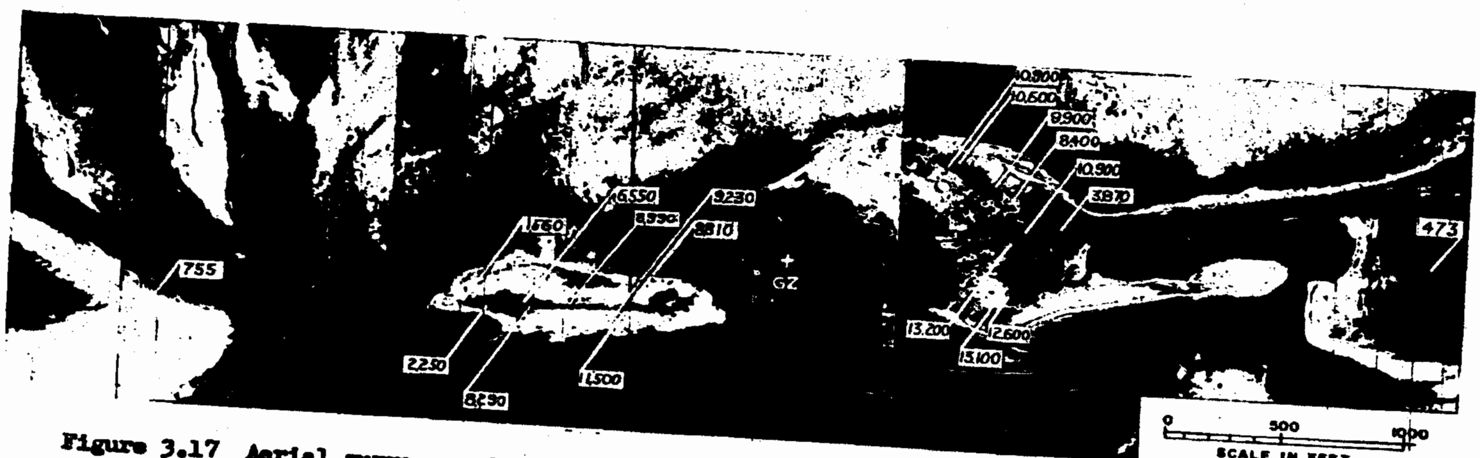

Figure 3.17 Aerial survey readings at 3 feet in the vicinity of the Mohawk crater, corrected to H+1 hour in r/hr.

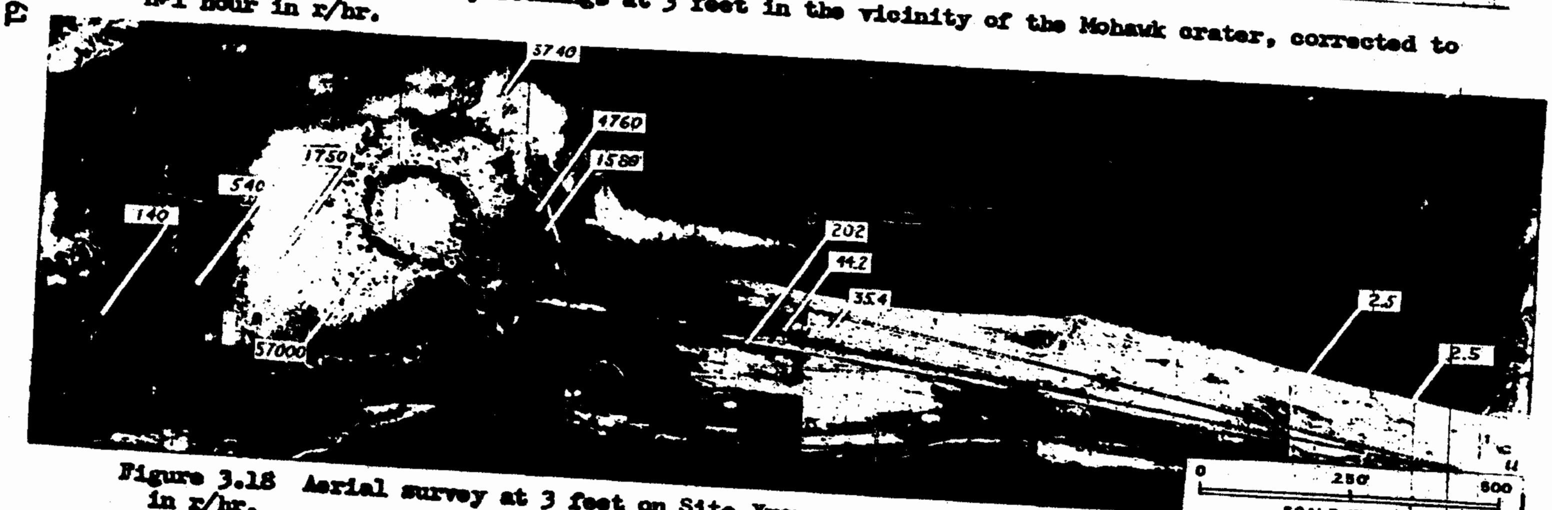

Figure 3.18 Aerial survey at 3 feet on Site Yvonne after Shot Lacrosse, corrected to H+1 hour in r/hr.

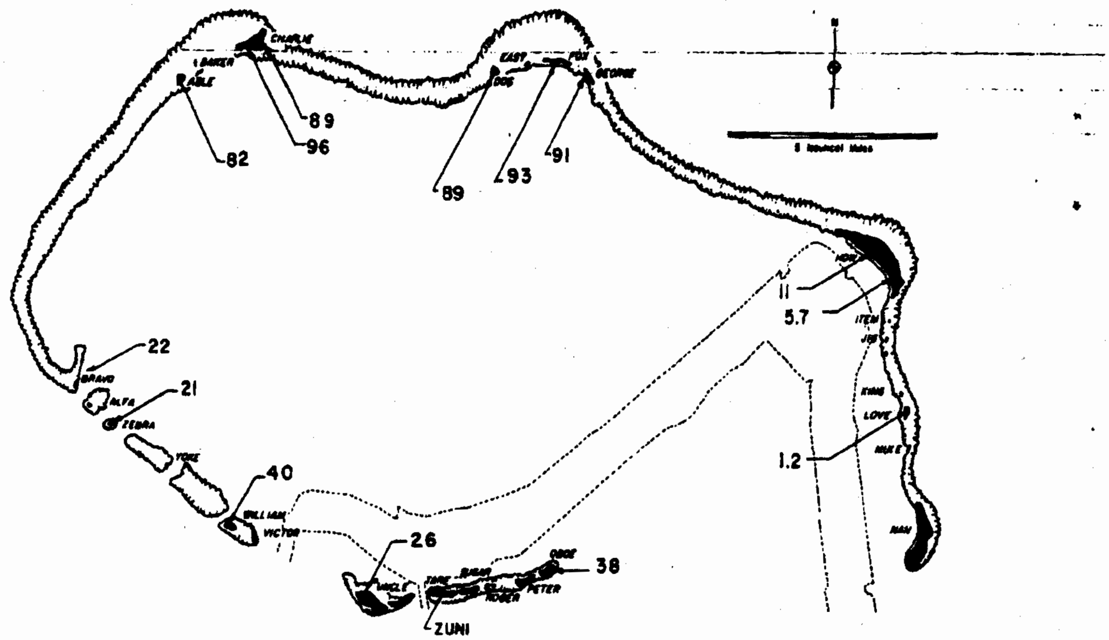

Figure 3.19 Zuni aerial survey readings at 3 feet, corrected to H+1 hour in r/hr.

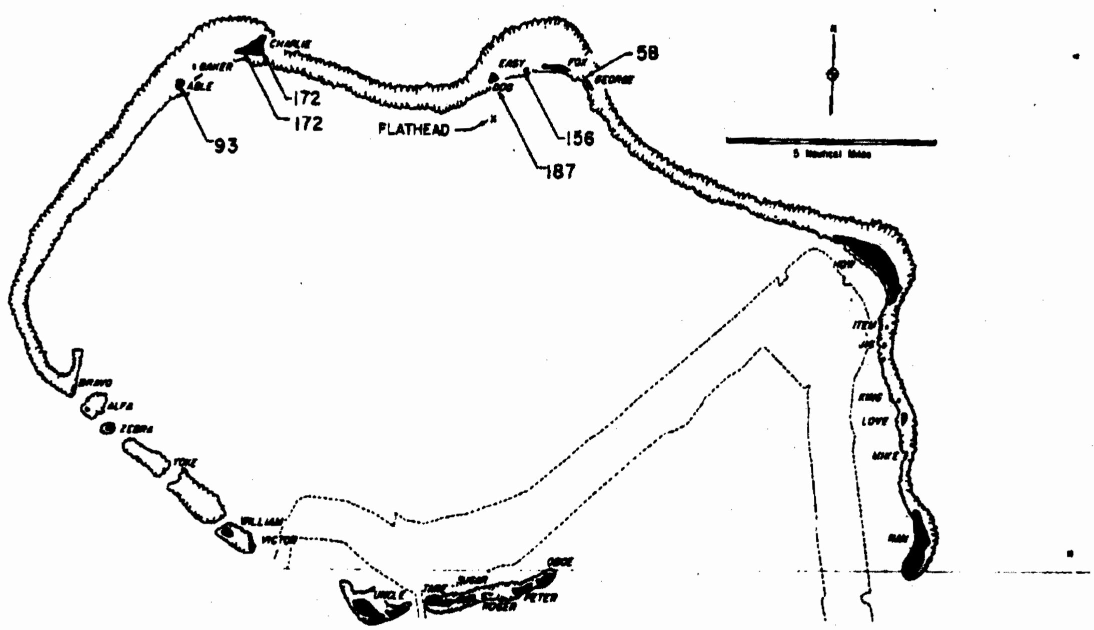

Figure 3.20 Flathead aerial survey readings at 3 feet, corrected to H+1 hour in r/hr.

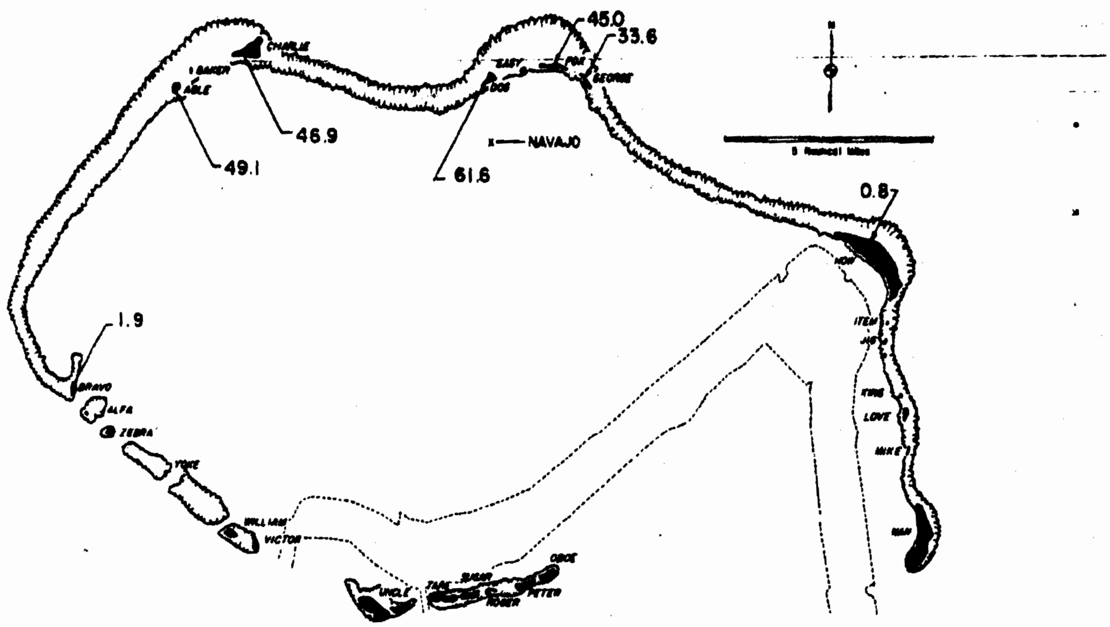

Figure 3.23 Navajo aerial survey readings at 3 feet, corrected to H+1 hour in r/hr.

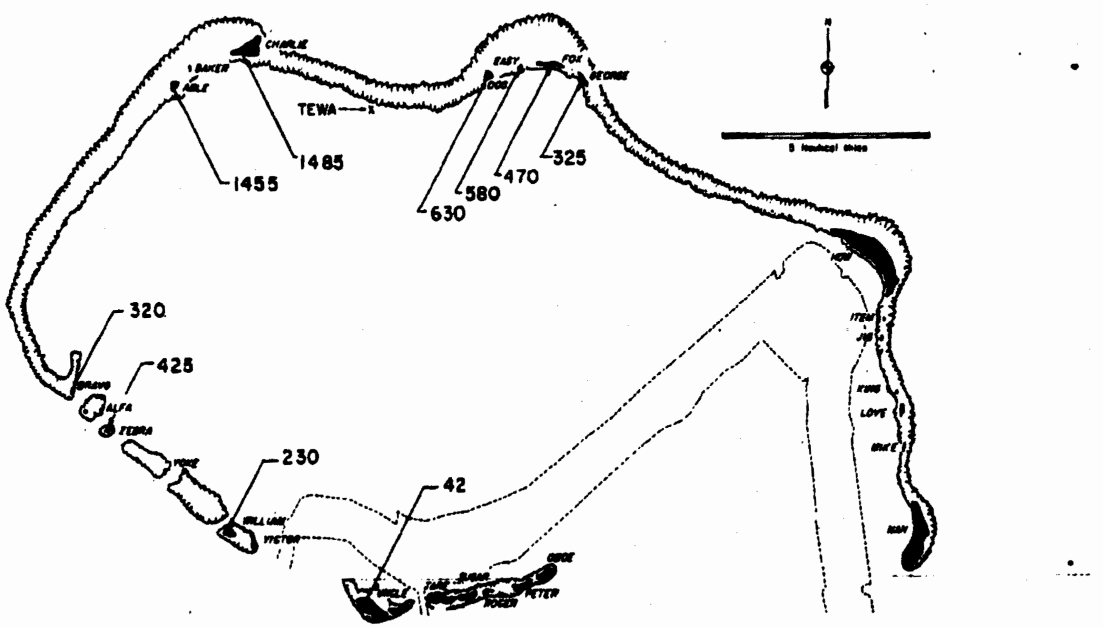

Figure 3.24 Tewa aerial survey readings at 3 feet, corrected to H+1 hour in r/hr.

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[redacted]

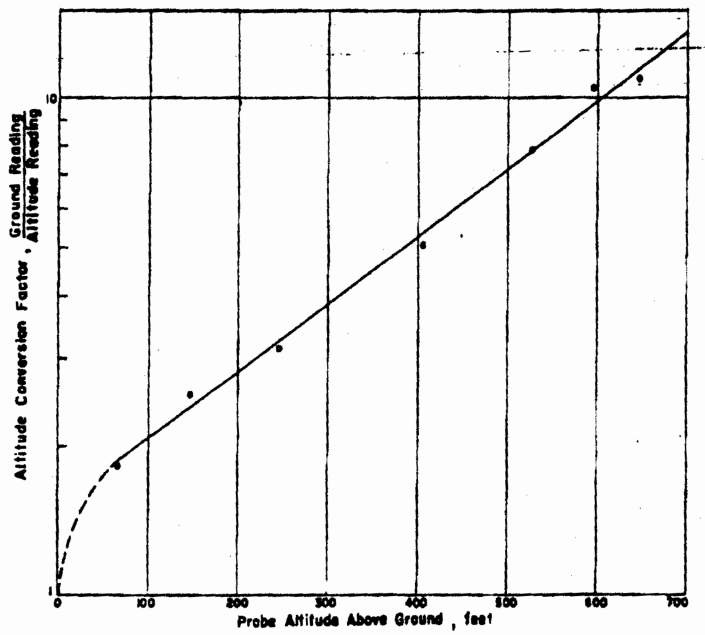

Figure 3.25 Zuni altitude-conversion factors. (Data taken at H+54 hr).

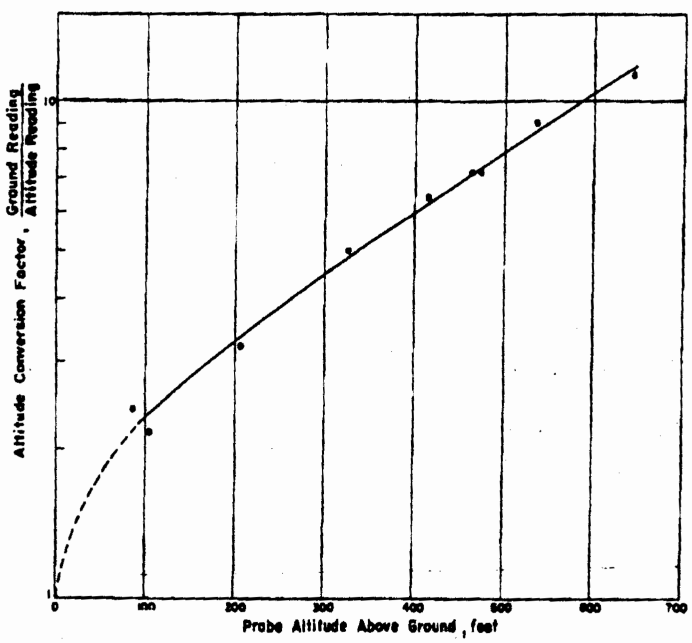

Figure 3.26 Flathead altitude-conversion factors. (Data taken at H+9 hr).

[redacted]

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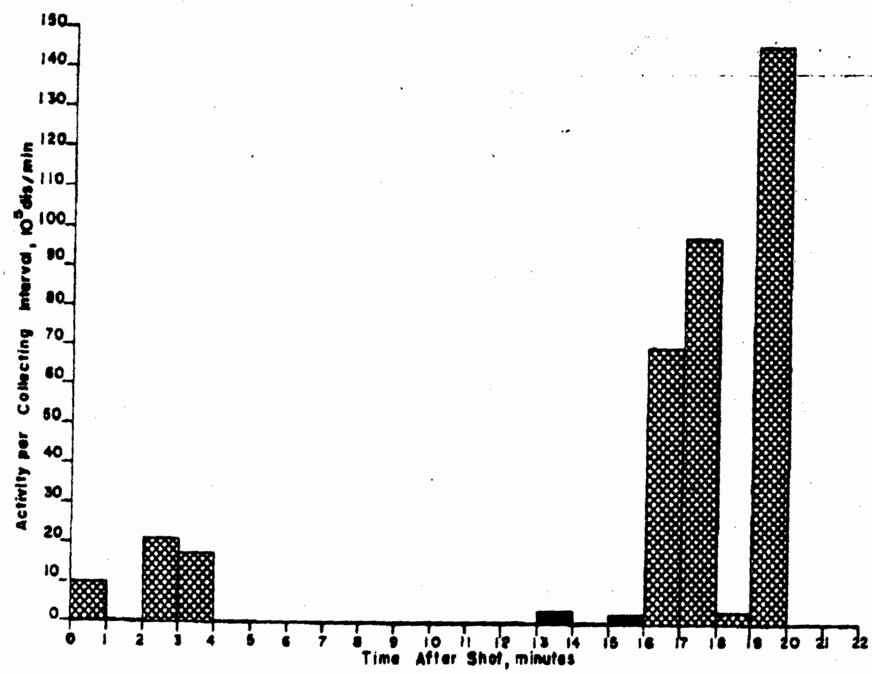

Figure 3.27 Activity collected by 1-minute-interval collector at Site Oboe for Shot Zuni.

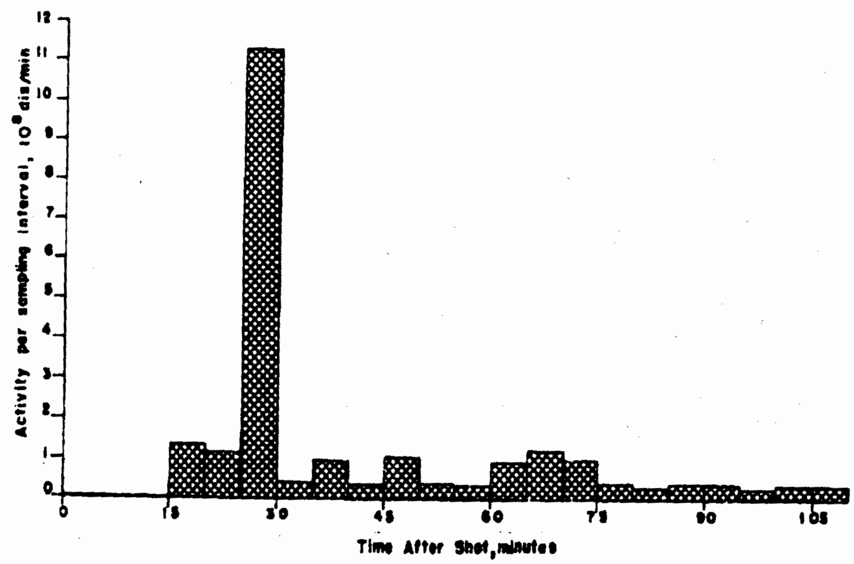

Figure 3.28 Activity collected by 5-minute-interval collector at Site William for Shot Zuni.

[redacted]

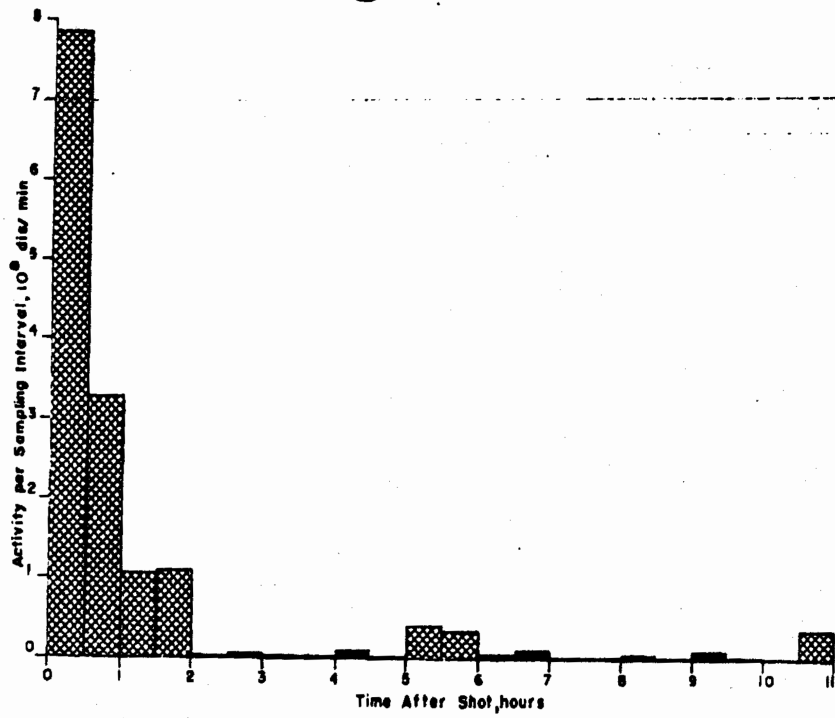

Figure 3.29 Activity collected by 30-minute-interval collector at Site William for Shot Zuni.

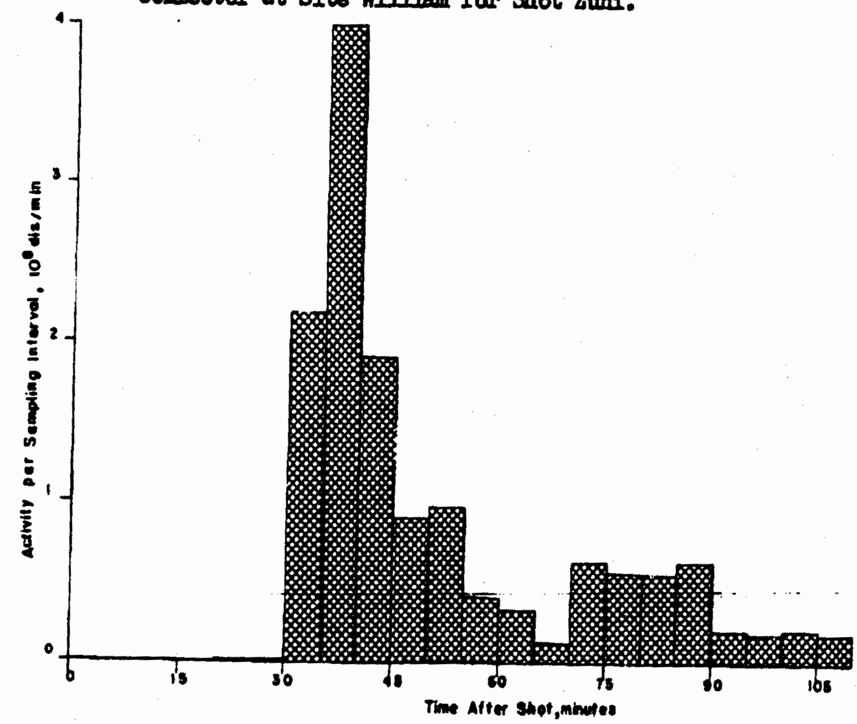

Figure 3.30 Activity collected by 5-minute-interval collector at Site Yoke for Shot Zuni.

[redacted]

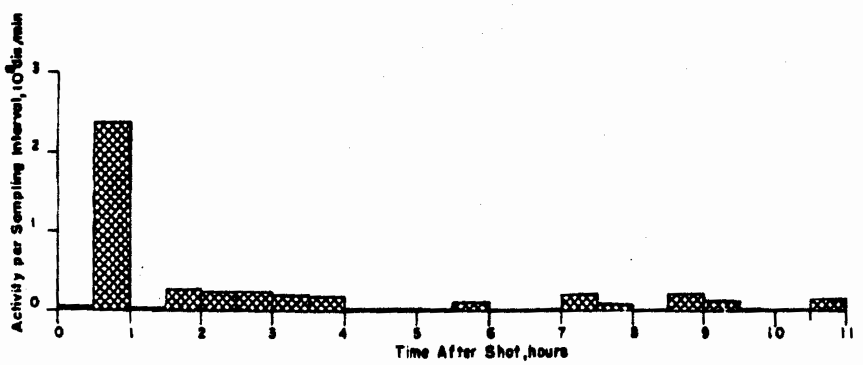

Figure 3.31 Activity collected by 30-minute-interval collector at Site Yoke for Shot Zuni.

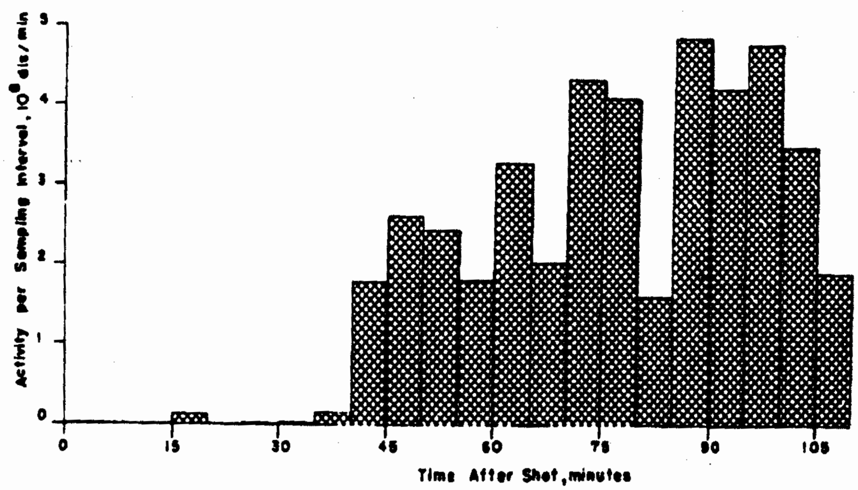

Figure 3.32 Activity collected by 5-minute-interval collector at Site Charlie for Shot Zuni.

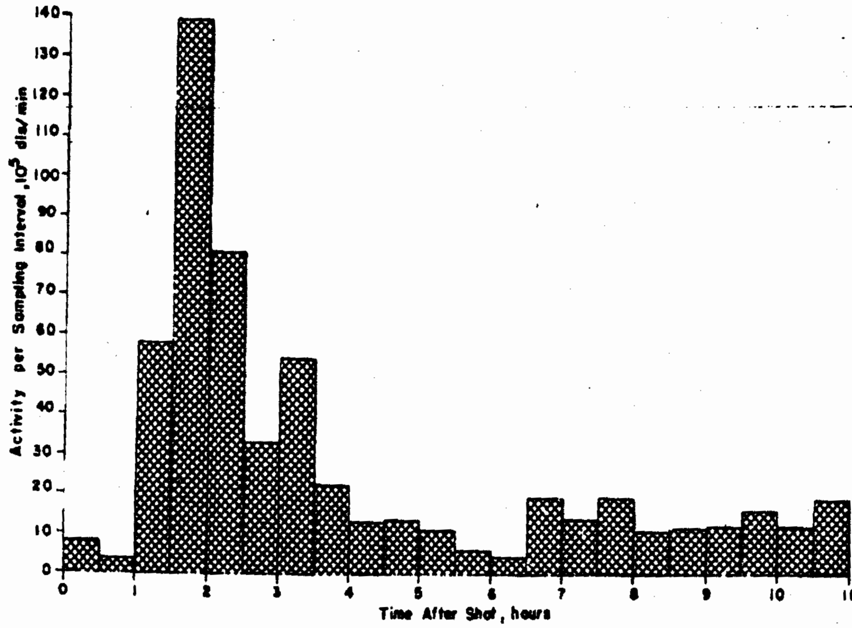

Figure 3.35 Activity collected by 30-minute-interval collector at Site Charlie for Shot Flathead.

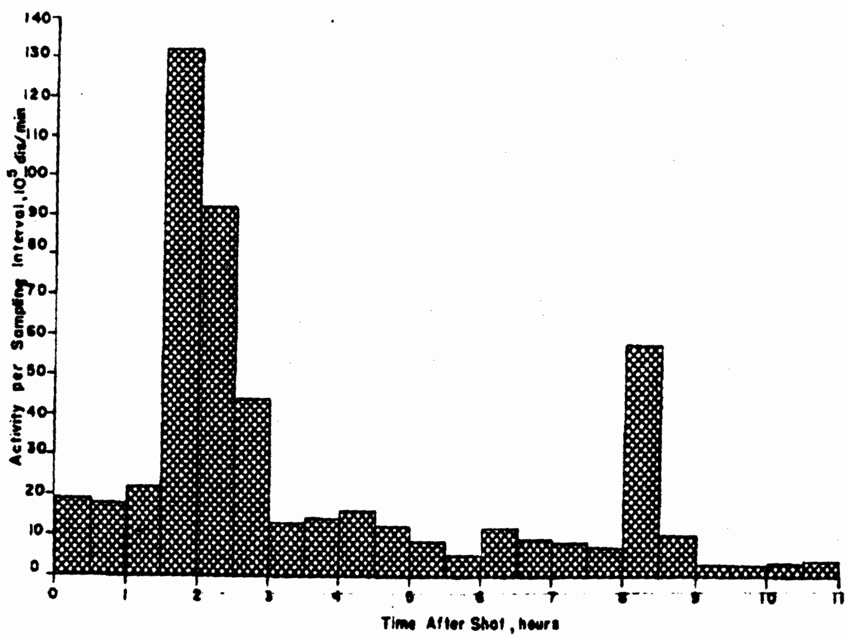

Figure 3.36 Activity collected by 30-minute-interval collector at Site George for Shot Flathead.

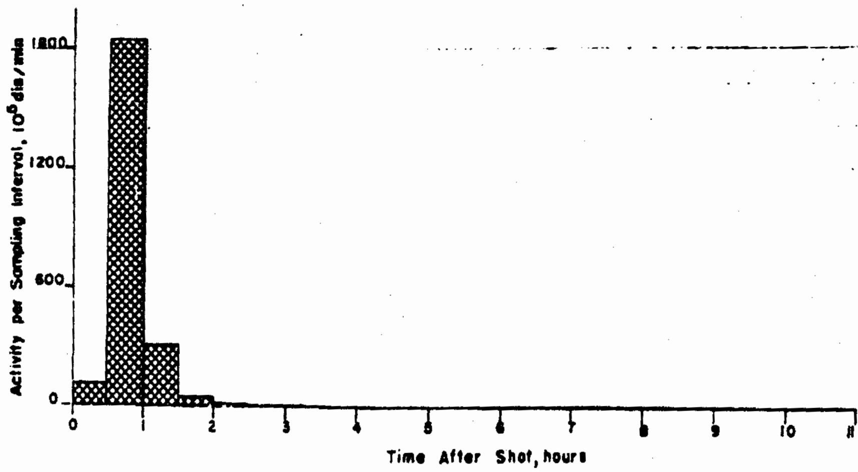

Figure 3.39 Activity collected by 30-minute-interval collector at Site Charlie for Shot Navajo.

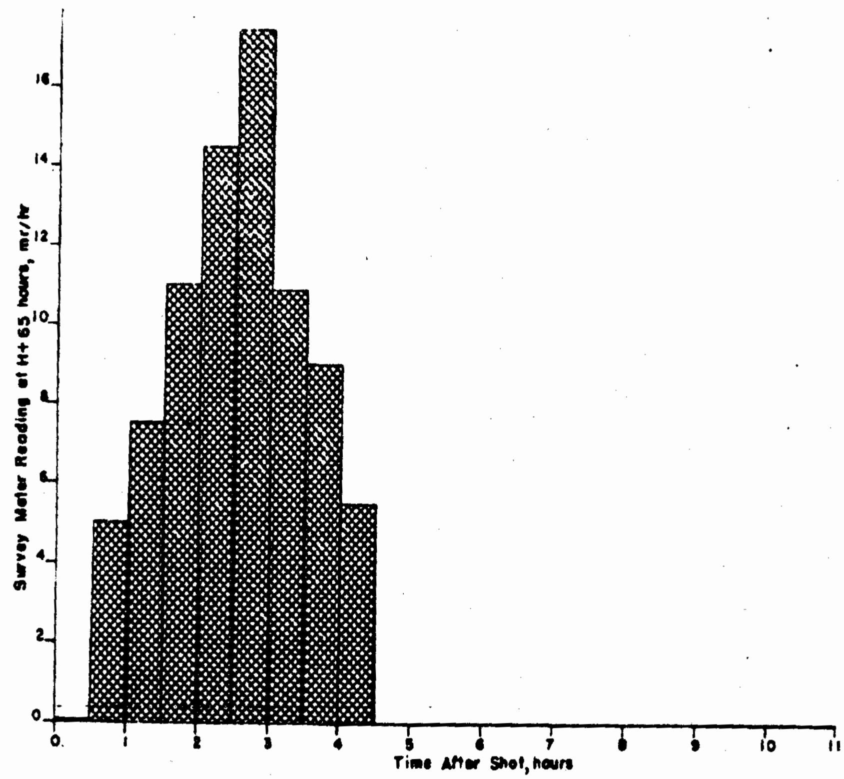

Figure 3.40 Activity collected by 30-minute-interval collector at Site George for Shot Tewa.

[redacted]

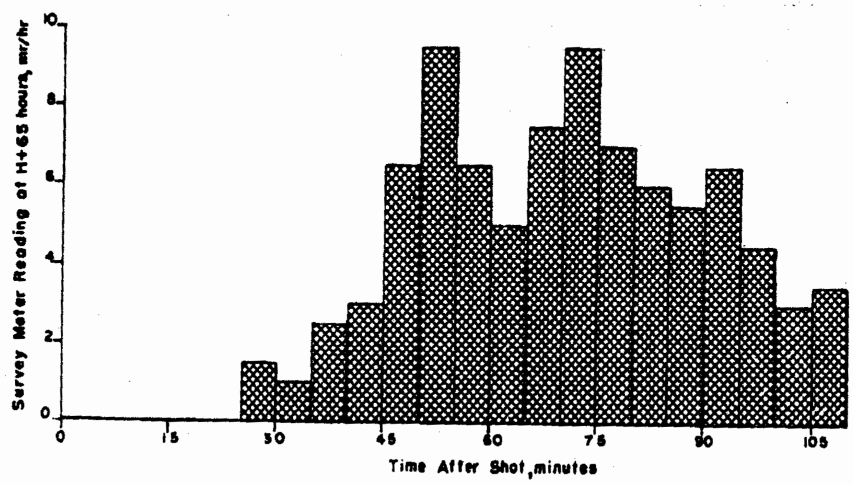

Figure 3.41 Activity collected by 5-minute-interval collector on YFNB-29 for Shot Tewa.

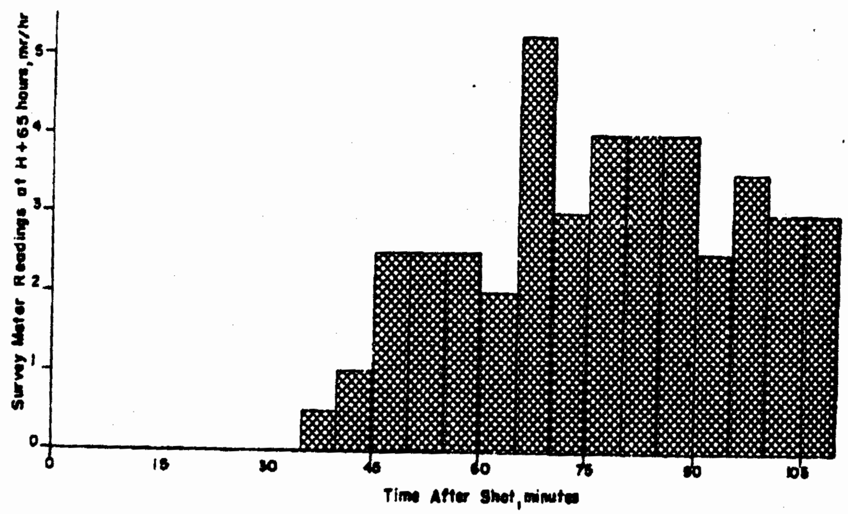

Figure 3.42 Activity collected by 5-minute-interval collector at Site Yoke for Shot Tewa.

[redacted]

[redacted]

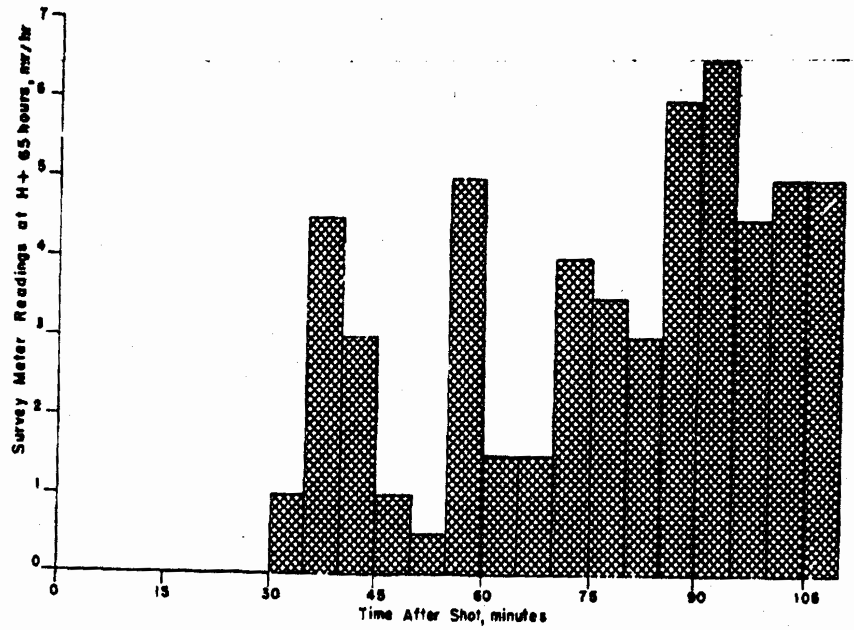

Figure 3.43 Activity collected by 5-minute-interval collector at Site William for Shot Tewa.

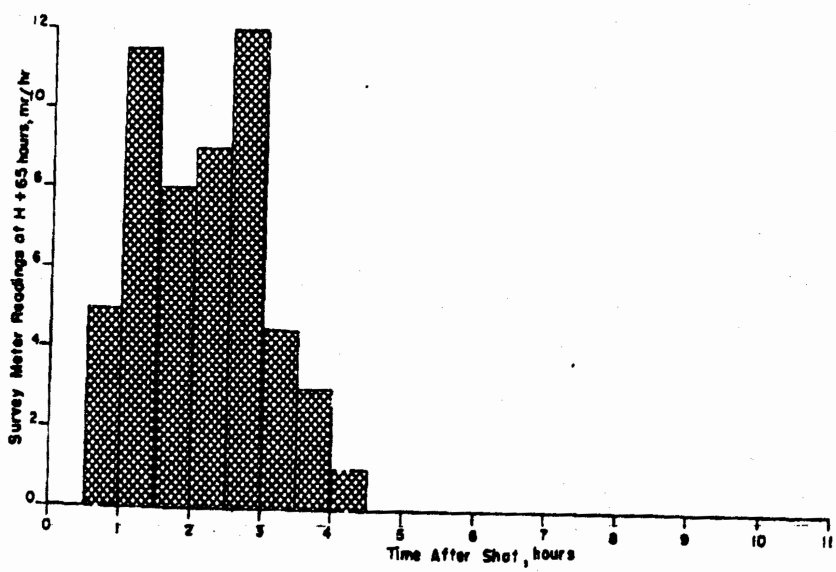

Figure 3.44 Activity collected by 30-minute-interval collector at Site William for Shot Tewa.

[redacted]

[redacted]

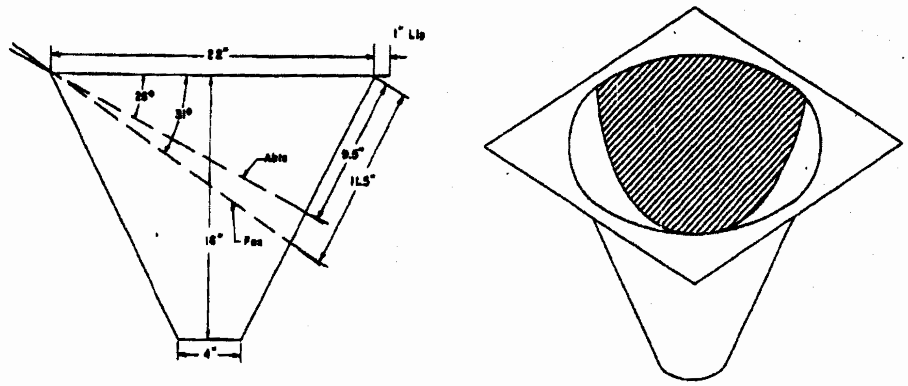

Figure 3.45 Pattern formed in gross-fallout collector by Flathead fallout, and maximum angle at which it entered.

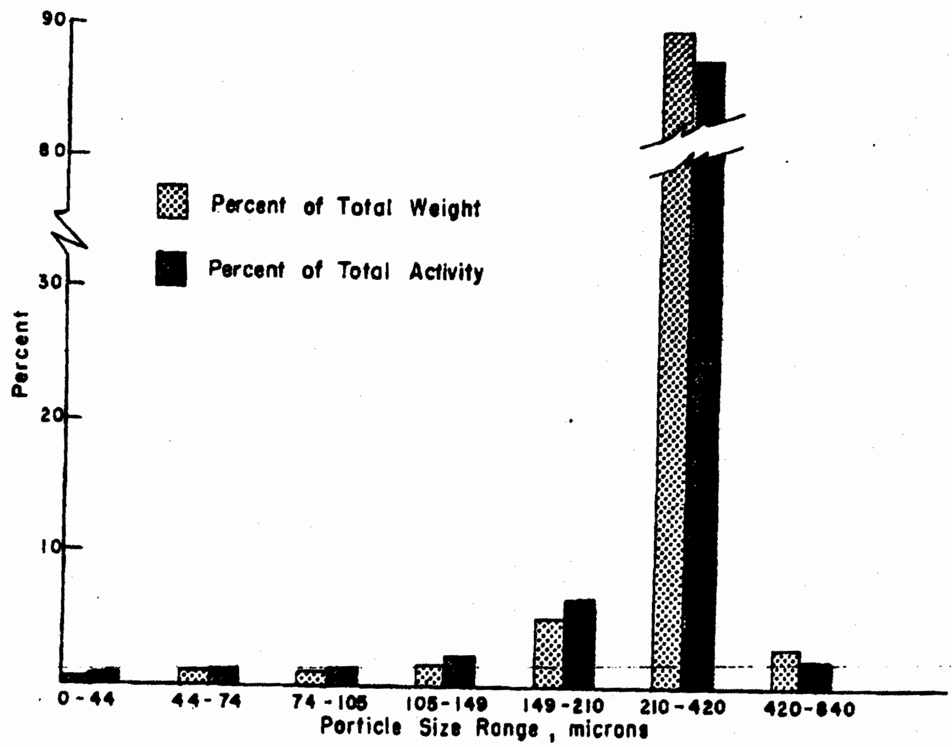

Figure 3.46 Weight and activity distribution for Gene Sample, Shot Lacrosse, 69,000 feet from ground zero.

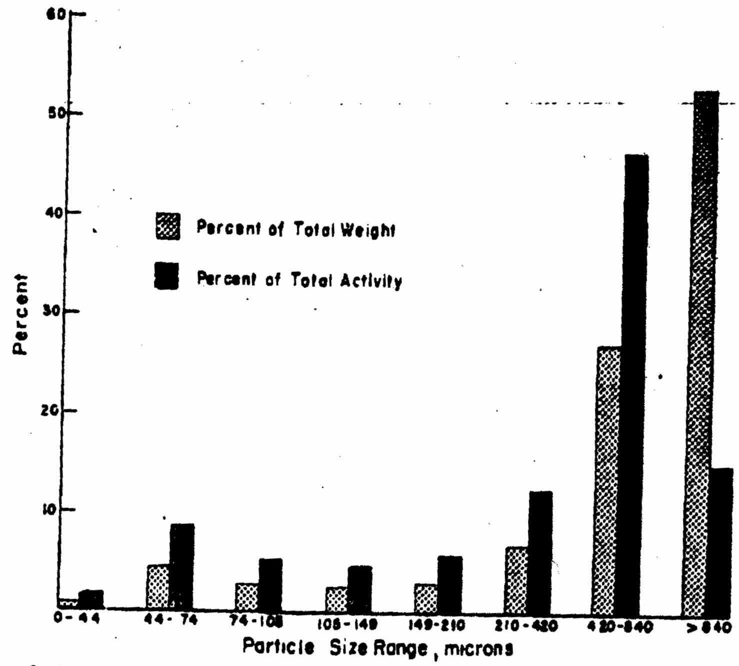

Figure 3.47 Weight and activity distribution for Yoke sample, Shot Zuni, 43,100 feet from ground zero.

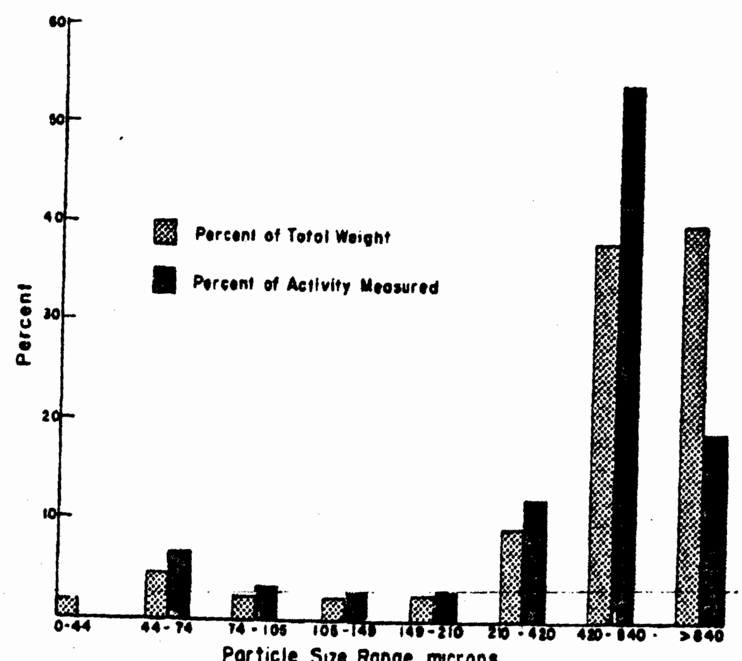

Figure 3.48 Weight and activity distribution for Bravo sample, Shot Zuni, 59,800 feet from ground zero.

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CHAPTER 4

DISCUSSION

4.1 DECAY MEASUREMENTS

The field gamma dose rate decay curves shown in Figures 3.1 to 3.5 were constructed by fitting a straight line to three points by inspection. The curves can only be expected to give a good indication of the order of magnitude of the overall decay slope for the first 50 hours after detonation. The relatively close agreement between the slopes of these field dose rate curves and the early slopes of the laboratory gamma dose rate decay curves, as shown in Table 3.2, indicates that, for short time intervals, normal weathering has little effect on contamination levels on the islands of the Pacific Proving Ground. Although a reduction of the contamination levels by the action of winds or water should cause an apparent increase in the rate of decay, the average field decay slope for Flathead was actually less than the slopes read from the first few points of the laboratory gamma dose rate decay curve for Flathead. Although small contamination levels resulting from Zuni existed immediately prior to Flathead, correction for these "background" readings has no significant effect upon the overall decay slope due to Flathead contamination. The dose rate readings on the islands due to the 14-day-old Zuni contamination were of the order of 150 to 200 mr/hr. The levels existing at about 9 hours after Flathead were of the order of 10,000 to 20,000 mr/hr. When all post-Flathead readings are corrected for the Zuni contamination, the average resulting decay slope is increased from 1.0 to 1.02.

The extremely heavy rains which occurred on D+1 day after Navajo and which continued for many hours did reduce the contamination levels resulting from this shot, as shown in Table 3.7. Apparent gamma decay slopes, based upon the D-day and D+1 day readings only, vary from -1.5 to -2.7 for all island sites surveyed except Bravo, where the apparent slope based on these two points is -0.98. Most of the surface of Bravo is extremely rocky, when compared to Sites Able through How, which have a sandy surface.

The significance of the beta decay curves will be discussed in the final report after a complete analysis of all data has been made.

4.2 AERIAL SURVEY DATA

During Shots Lacrosse and Mohawk, emphasis was placed upon obtaining dose rate readings near the craters. The high readings obtained in the

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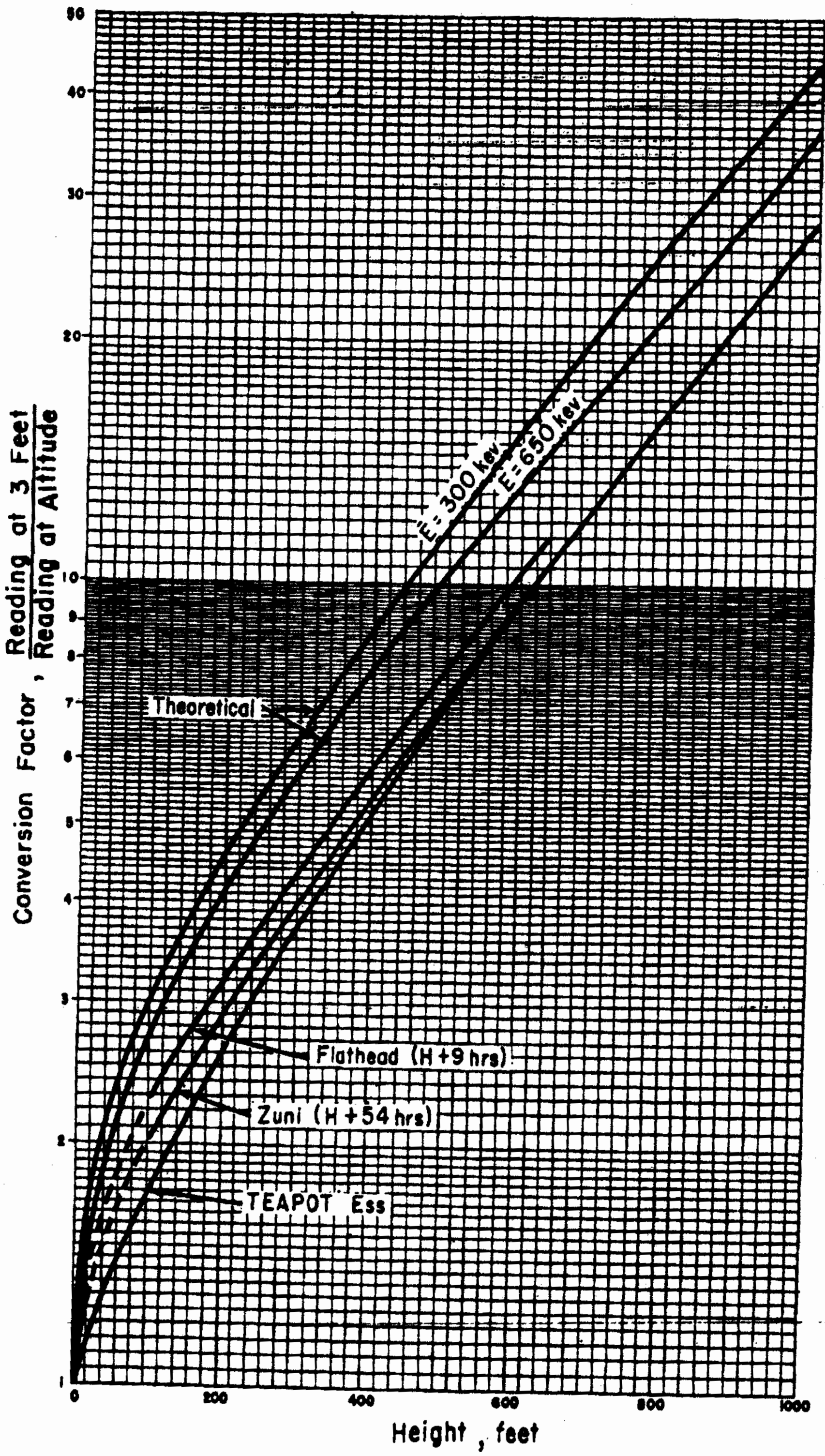

Figure 4.1 Gamma dose-rate conversion factors.

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4.4 TIME OF ARRIVAL, RATE, AND DURATION OF FALLOUT

The period during which significant fallout was collected and the time at which the maximum rate of fallout occurred are summarized in Table 4.1 for all shots in which time-incremental samples were collected. Also included in the table are the times at which the dose rate reached

TABLE 4.1 TIME OF ARRIVAL, RATE, AND DURATION OF SIGNIFICANT FALLOUT ACTIVITY

Shot	Station	Distance From Ground Zero	Interval During Which Fallout Occurred	Time of Maximum Rate of Fallout From IFC's	Time at Which Dose Rate was Maximum From Project 2.2
		ft		min	min
Zuni	Oboe	16,000	16 min to >22 min	19 to 20	
	William	35,000	15 min to 2.5 hr	25 to 30	
	Yoke	43,000	30 min to 1.5 hr	35 to 40	
	Charlie	78,000	40 min to 3.5 hr	85 to 90	
Flathead	George	15,050	<30 min to >10 hr	90 to 120	40
	Charlie	36,780	<30 min to >10 hr	90 to 120	
Navajo	Charlie	37,790	30 min to 2 hr	45 to 50	80
Tewa	George	31,690	30 min to 4.5 hr	150 to 180	
	YFNB-29	41,400	25 min to >110 min	50 to 75	
	Yoke	56,240	35 min to >110 min	65 to 70	
	William	59,400	30 min to 4.5 hr	150 to 180	

its maximum value, as determined by the Project 2.2 residual dose rate recorder.

4.5 WEIGHT AND ACTIVITY OF THE FALLOUT SAMPLES

The activity concentrations of the fallout from both Shots Lacrosse and Zuni were higher at the distant stations than at the relatively close-in stations. Table 3.11 shows that the activity per unit weight of the Zuni sample collected on the YAG-40 at a distance of approximately 50 miles was much larger than for samples collected within the area of the atoll. A comparison of the weight and activity distributions for the YAG-40 samples and the island samples shown in Figures 3.46 through 3.50 indicate that the distant samples had a much smaller percentage of particles in the larger size ranges.

The problems encountered in obtaining representative samples from the Flathead and Navajo barge shots and in recovering the active material from the collectors suggest that large fractions of the activity reached the surface as liquid droplets. Although some dry solid material was collected after each of these shots, the greater portion of the activity was associated with a wet slurry or was observed on collecting surfaces which, in some instances, showed small spots where liquid droplets had dried.

A comparison of the weight or particle-size distribution of the solid portion of the fallout with its activity or with the total activity collected is of doubtful value.

The data on the samples from the intermittent fallout collectors on Charlie and George during Shot Flathead are included in Table 3.10 for

(b) (3)

Since the 210-to-420-micron size range (in which the activity of the black particles was measured) made up 87 percent of the Lacrosse fallout activity, 25 percent contribution of the black particles to the total activity can be considered to be approximately correct for the Lacrosse fallout, in general.

The spherical particles in the Zuni fallout were probably condensed from fireball material as CaO, and the subsequent action of moisture and atmospheric CO_2 produced the observed carbonate shell. Further action of CO_2 would account for the eventual disintegration of these particles.

It was pointed out in Section 3.6.2 that the fallout scooped from the deck of the YAG-40 was heavily agglomerated in the higher size ranges and that water broke up the agglomerates into a suspension of fine particles (50 microns or less) in a $NaCl$ solution. The obvious conclusion is that the agglomeration was caused by salt spray.

It was anticipated that the significant fallout from water-surface shots would be liquid. It was therefore surprising to find little liquid in the Flathead samples. Instead, the overwhelming majority of the activity appeared in an aqueous slurry of $NaCl$ crystals, Fe_2O_3 particles, and fine $CaCO_3$ particles. The Fe_2O_3 most likely came from the barge itself. The $CaCO_3$ probably resulted from the 200 tons of coral ballast on the barge. Although one would expect this material to result in CaO or $Ca(OH)_2$ particles, the particles found were small enough that they might have been readily converted to the carbonate. The $NaCl$, originating from sea water, may have been in solution when it fell out and crystallized because of evaporation. The large, discrete, $CaCO_3$ particles found in the intermittent collectors and in the apices of the gross collectors are more difficult to explain. The virtual absence of $Ca(OH)_2$ in these particles and their low activity obviate their having been incorporated in the fireball, as would have been the case with the ballast coral. A possible explanation may be that these particles originated from the floor of the lagoon, whence they were drawn up mechanically into the column of the cloud. The presence of more solid material in Shot Flathead than in the CASTLE barge shots, upon which the expectations were based, may be explained by the comparatively high yields of the latter, which would cause wider dispersion of barge material.

(b) (3)

(b) (3)

[redacted] However, since it has been shown in Section 3.5 that the intermittent collectors did not collect the most significant type of Flathead fallout material (viz, the brown mud), the IFC radiochemical results cannot be considered representative of the true fallout.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

The tentative conclusions presented in this report are based upon a preliminary evaluation of the data. They may be changed upon further analysis of the present data or upon the development of additional data at the laboratory.

Data from other projects will be required before conclusions can be drawn on Objectives 2 and 3.

5.1 CONCLUSIONS

1. The Cherokee air burst did not produce significant fallout in the Bikini Atoll.
2. The early field gamma-dose-rate decay for fallout-contaminated islands in the Pacific Proving Ground is not significantly affected by the usual conditions of wind and rain. However, extremely heavy rains lasting for several hours will, in the case of water-surface shots, increase the apparent rate of field gamma decay.
3. The aerial survey instrument used by this project provides a practical means of determining precise contamination levels at surface locations in high radiation fields.
4. The maximum radiation dose rates observed on the ground near the Lacrosse and Mohawk craters were higher than those reported after any previous nuclear detonation.
5. The activity per unit weight of fallout resulting from land-surface bursts is higher at distant stations than at relatively close-in stations.
6. For water-surface shots, fallout-sampling devices different from those used are required to collect meaningful samples.
7. Seventy-five percent of the Lacrosse fallout activity was contributed by partially calcined coral particles which became contaminated throughout by contact with radioactive liquid.
8. Twenty-five percent of the Lacrosse fallout activity was contributed by sintered, black particles which contained iron.

(b) (3)

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APPENDIX A

EXPERIMENTAL EQUIPMENT

A.1 INTERMITTENT FALLOUT COLLECTOR

The intermittent fallout collector (IFC) is a modification of the collector used during Operations IVY, CASTLE, and TEAPOT (References 8, 9, and 11). It consists of a circular steel tub, 40 inches in diameter and 24 inches in height; a circular disc or spider, divided into 24 sectors; a driving and timing mechanism; and a power supply. Twenty-two triangular sampling trays, each 3 3/8 by 10 by 3/4 inches deep, are placed into the sectors. The first and last sector are left empty. One tray at a time is exposed to bass surge or fallout or both through an opening the size of the sampling tray in the top cover. A door covers the sampling opening both before the initial and after the final sampling time.

The instrument is started by an external timing signal. A self-contained interval clock timer controls a mechanism which moves the trays into sampling position. Succeeding trays move into position under the cover opening at set time intervals until the cycle is completed, after which the door closes and the machine shuts itself off. Two views of the intermittent fallout collector are shown in Figures A.1 and A.2.

A.2 GROSS-FALLOUT COLLECTOR

The gross-fallout collector is composed of a metal support framework and a conical liner with a door covering the opening. The liner has an opening approximately 2 feet in diameter at the top. In the bottom of the cone, which is 5 inches in diameter, is a stainless-steel filter. There is a small hose below this going to a polyethylene bottle. Figure A.3 shows the collector with the door open, and Figure A.4 shows the device with the door closed.

The door opens and closes with a sliding action. It has a notched strip rack on its top and is driven by a 24-volt direct-current motor through a chain-and-gear drive system. The sliding motion of the door is stopped when the door trips a microswitch at either the full-open or the full-closed position.

The control system consists of a power relay for the control circuitry, a power relay for the motor, a reversing relay for the armature, and a timing system composed of a direct-current motor and a preset register. The control system is actuated by the closing of a relay in an Edgerton, Germeshausen, and Grier, Inc. (EG&G) blue box at the time